MINERALS AND METALS

A REFERENCE-BOOK

USEFUL DATA AND TABLES OF INFORMATION

ON

LEGAL, CUSTOMARY, AND SCIENTIFIC MEASUREMENTS; GEOLOGICAL CLASSIFICATION; ROCK COMPOSITION; CHEMISTRY, DRY AND WET ASSAY; MINERALOGY; METALLURGY; METAL FOUNDING AND PLATING; HYDRAULICS; WATER PURIFICATION; MINERAL OILS; GASES, EXPLOSIVES; STRENGTH OF MATERIALS, INCLUDING WOODS, THEIR PROPERTIES, ADAPTABILITY, AND PRESERVATION; PIGMENTS, GUMS, AND SOLVENTS FOR PAINTS AND VARNISHES; MISCELLANEOUS DATA AND RECEIPTS

A CONDENSED COMPILATION FROM VARIOUS SOURCES

BY

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The Publishers and the Author will be grateful to any of the readers of this volume who will kindly call their attention to any errors of omission or of commission that they may find therein. It is intended to make our publications standard works of study and reference, and, to that end, the greatest accuracy is sought. It rarely happens that the early editions of works of any size are free from errors; but it is the endeavor of the Publishers to have them removed immediately upon being discovered, and it is therefore desired that the Author may be aided in his task of revision, from time to time, by the kindly criticism of his readers.

JOHN WILEY & SONS.

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PREFACE.

THE information relating to the various subjects treated in this little volume is condensed into the smallest possible space by being mostly arranged into tabular form. It is a matter of daily experience that practical men using reference books of this kind obtain the information required principally from tables contained therein.

With the exception of mathematical tables or tables o measurements, tabular information cannot be expected to be more than approximate Whenever minute descriptions of chemical operations or manipulations are required, such should be obtained from text-books treating on the specific matter under consideration.

The mineralogical tables, which have been constructed from information derived from a number of authoritative publications, are considered to be entirely new and are offered here as an experimental means for the approximate determination of the composition of any mineralogical specimen qualitatively, and as a preliminary means of investigation to determine the desirability for a quantitative chemical analysis.

By an examination of the mineralogical tables, and especially by their employment for the determination of the characteristics of some specimens, it will be perceived that, for many minerals named in the tables, the information is not as complete as may be desirable, and that therefore a thorough comparison cannot be made, as under some headings of the tables the corresponding characteristic behavior of the mineral, substance is wanting.

This omission is due to the fact that the information relating to the tabulated minerals, when treated as indicated in the

tables, has been gleaned from descriptive matter disseminated in a number of books on mineralogy, none of which supplemented what was omitted in others.

The system of making tests in the manner indicated by the headings of the mineralogical tables does not exclude additional tests, and the tables themselves may be subjected to modifications and additions. It is therefore hoped that the systematic manner for the determination of the behavior of any mineral sample, when subjected to the physical tests and to the chemical reagents indicated in the tables, and when said behavior is recorded in accordance thereof, will be of service and assistance not only to the student but also to the numerous interested persons who have received no previous training in the science of mineralogy.

The part relating to metallurgy, although principally confined to matters generally familiar to the professional metallurgist, may nevertheless be found useful as an aid to memory to the latter, and will undoubtedly be of interest to the many persons who are in some way connected with or interested in trades in which metals of various kinds form the bulk of the raw material.

The application of electricity to metallurgy is in many cases limited to transitory methods, but is in a condition of development. The only practical and industrial application of electrical currents to metallurgical operations up to date appear to be confined to plating, refining of copper, to the reduction of aluminium, and of a few other metals of very limited use.

It has been found impracticable in a great many cases to give specifically credit to the source from which the information contained in this little volume was obtained, as in such cases information relating to the same subject-matter was gleaned from a number of authorities and is the result of contraction, condensation, and reclassification of matter drawn therefrom.

It has therefore been considered sufficient to enclose a list of the authorities which have been directly or indirectly instrumental to furnish material for the compilation of this little but it is hoped useful reference book.

J. G. GOESEL.

ST. LOUIS, MO., June, 1906.

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1. ALGEBRAIC SIGNS AND ABBREVIATIONS

Sign	Name	Explanation	Example	Remarks
$+$	Plus	Addition	$7+5=12$	
$-$	Minus	Subtraction	$7-5=2$	
$\times$	Times	Multiplication	$7\times5=35$	
	"	"	$a\times b=a.b=ab$	When used with letters
$\div$	Divided by	Division	$35\div7=\frac{35}{7}=5$	
$=$	Equal	Equality	$6\times4=3\times8$	
$\backsim$	Difference	Subtraction	$a\backsim b$	Subtract the smaller from the larger
$<$, ⅂	Larger than	Inequality	$a>b=a$ ⅂ b	*a* larger than *b*
$>$, ⅃	Less than	"	$a<b=a$ ⅃ b	*a* less than *b*
( )	Parentheses		$(3+2)\times5=25$	
[ ]	or Brackets		$[9-5]7=28$	
.	Decimal point	Decimal fraction	$5.34=5\frac{34}{100}$	Used with numbers only
°	Degree	$\frac{1}{360}$ of a circle	18°	For angles and temperatures
′	Minute	$\frac{1}{60}$ degree	7′	For angles only
″	Second	$\frac{1}{60}$ minute	15″	" " "
′	Feet		8′ = 8 feet	Measure of length
″	Inches	$\frac{1}{12}$ foot	5″ = 5 inches	" " "
sq., □	Square		3″□ = 3 square inches	Measure of surface
cb., ⊠	Cube		5″⊠ = 5 cubic inches	Measure of volume
x^2	Square	$x\times x$	$4^2=4\times4=16$	Surface in square units
x^3	Cube	$x\times x\times x$	$3^3=3\times3\times3=27$	Volume in cubic units
$x^{\frac{1}{2}}=\sqrt{x}$	Square root		$\sqrt{16}=16^{\frac{1}{2}}=4$	Side of given square
$x^{\frac{1}{3}}=\sqrt[3]{x}$	Cube root		$\sqrt[3]{27}=27^{\frac{1}{3}}=3$	Side of given cube
: ∷ :	is to, as, is to	Proportion	3:4::9:12	Also $\frac{3}{4}=\frac{9}{12}$
π, p	Periphery	Number	3.14159265	Circumference of circle if the diameter is = 1
mt	Metre	Unit of length	6 mt	Length
c	Centimetre	0.01 mt	5 c	"
mm	Millimetre	0.001 mt	8 mm	"
lt	Litre	Unit of capacity	15 lt	Volume
cc	Centimetre cube	0.001 lt	9 cc	"
gm	Gramme	Unit of weight	132 gm	Weight
kgm	Kilogramme	Unit of weight	17 kgm	"

MINERALS AND METALS.

UNITED STATES COAST AND GEODETIC SURVEY:

BUREAU OF WEIGHTS AND MEASURES.

2. HISTORIC EXTRACT FROM OFFICIAL PAPERS RELATING TO STANDARDS OF WEIGHTS AND MEASURES OF THE UNITED STATES.

In 1814 the Troughton 82-inch brass scale was ordered by Hassler as a standard of length for the Coast and Geodetic Survey.

In 1821 a platinum kilogramme and metre and in 1827 a brass Troy pound were obtained by Albert Gallatin, Minister of the United States in London.

In 1828, by Act of Congress of May 19th, this Troy pound was made the standard for the use of the Mint.

Customary Measure of Length.—The Treasury Department adopted as its *yard* the length comprised between the 27th and the 63d inch division of the Troughton scale, which was supposed to be equal to the Imperial Standard of Great Britain, but surpassed it in length by 0.00083 inch at 62° F.

In 1834 the British standard of length was destroyed by fire, and a new standard was constructed after 1843. From this fifty copies were made, and two of these copies, the Low Moor Iron No. 57 and the Bronze No. 11, were presented to the United States in 1856. These yards were again taken to England in 1876 and in 1888 for comparison with the Imperial Standard, and their relation to the latter is therefore kn

UNITED STATES STANDARD WEIGHTS AND MEASURES.

Conversion of Customary to Metric and of Metric to Customary Weights and Measures.

CUSTOMARY TO METRIC.

Linear.

	Inches to Millimetres.	Feet to Metres.	Yards to Metres.	Miles to Kilometres.
1 =	25 4001	0 304801	0 914402	1 60935
2 =	50 8001	0 609601	1 828804	3 21869
3 =	76 2002	0 914402	2 743205	4.82804
4 =	101 6002	1 219202	3 657607	6.43739
5 =	127 0003	1 524003	4 572009	8 04674
6 =	152 4003	1 828804	5 486411	9 65608
7 =	177 8004	2 133604	6 400813	11 26543
8 =	203.2004	2 438405	7 315215	12 87478
9 =	228.6005	2 743205	8 229616	14.48412

Square.

	Square Inches to Square Centimetres.	Square Feet to Square Decimetres.	Square Yards to Square Metres.	Acres to Hectares.
1 =	6 452	9 290	0 836	0 4047
2 =	12 903	18 581	1 672	0.8094
3 =	19 355	27 871	2 508	1.2141
4 =	25 807	37 161	3 344	1 6187
5 =	32 258	46 452	4 181	2.0234
6 =	38 710	55 742	5 017	2 4281
7 =	45 161	65 032	5 853	2 8328
8 =	51 613	74 323	6 689	3.2375
9 =	58.065	83.613	7 525	3.6422

Cubic.

	Cubic Inches to Cubic Centimetres.	Cubic Feet to Cubic Metres.	Cubic Yards to Cubic Metres.	Bushels to Hectolitres.
	16 387	0.02832	0.765	0.35239
	32 774	0 05663	1 529	0.70479
	49.161	0 08495	2.294	1.05718
	65.549	0 11327	3.058	1.40957
	81.936	0 14158	3.823	1.76196
	[illegible]8 323	0 16990	4 587	2 11436
	[illegible].710	0.19822	5 352	2 46675
	[illegible]097	0.22654	6 116	2 81914
	[illegible]84	0 25485	6.881	3.17154

Capacity.

	Fluid Drams to Millilitres or Cubic Centimetres.	Fluid Ounces to Millilitres.	Quarts to Litres.	Gallons to Litres.
1	3.70	29.57	0.94636	3.78543
2	7.39	59.15	1.89272	7.57087
3	11.09	88.72	2.83908	11.35630
4	14.79	118.29	3.78543	15.14174
5	18.48	147.87	4.73180	18.92717
6	22.18	177.44	5.67816	22.71261
7	25.88	207.02	6.62452	26.49804
8	29.57	236.59	7.57088	30.28348
9	33.27	266.16	8.51724	34.06891

Weight.

	Grains to Milligrammes.	Avoirdupois Ounces to Grammes.	Avoirdupois Pounds to Kilogrammes.	Troy Ounces to Grammes.
1	64.7989	28.3495	0.45359	31.10348
2	129.5978	56.6991	0.90719	62.20696
3	194.3968	85.0486	1.36078	93.31044
4	259.1957	113.3981	1.81437	124.41392
5	323.9946	141.7476	2.26796	155.51740
6	388.7935	170.0972	2.72156	186.62088
7	453.5924	198.4467	3.17515	217.72437
8	518.3914	226.7962	3.62874	248.82785
9	583.1903	255.1457	4.08233	279.93133

1 Gunter's chain = 20.1168 metres
1 sq. statute mile = 259.000 hectares
1 fathom = 1.829 metres
1 nautical mile = 1853.25 metres
1 foot = 0.304801 metre, 9.4840158 log.
1 avoir. pound = 453.5924277 gramme
15432.35639 grains = 1 kilogramme

METRIC TO CUSTOMARY.

Linear.

	Metres to Inches.	Metres to Feet	Metres to Yards	Kilometres to Miles.
1 =	39 3700	3 28083	1 093611	0 62137
2 =	78 7400	6 56167	2 187222	1 24274
3 =	118 1100	9 84250	3 280833	1.86411
4 =	157 4800	13 12333	4 374444	2 48548
5 =	196 8500	16 40417	5 468056	3 10685
6 =	236 2200	19 68500	6 561667	3 72822
7 =	275 5900	22 96583	7 655278	4 34959
8 =	314 9600	26 24667	8 748889	4 97096
9 =	354 3300	29 52750	9 842500	5 59233

Square.

	Square Centimetres to Square Inches	Square Metres to Square Feet.	Square Metres to Square Yards.	Hectares to Acres.
1 =	0.1550	10 764	1 196	2 471
2 =	0.3100	21 528	2 392	4 942
3 =	0 4650	32 292	3 588	7 413
4 =	0.6200	43 055	4 784	9 884
5 =	0 7750	53 819	5 980	12 355
6 =	0 9300	64 583	7 176	14 826
7 =	1 0850	75 347	8 372	17 297
8 =	1.2400	86 111	9 568	19 768
9 =	1.3950	96.875	10.764	22 239

Cubic.

	Cubic Centimetres to Cubic Inches.	Cubic Decimetres to Cubic Inches.	Cubic Metres to Cubic Feet.	Cubic Metres to Cubic Yards.
1 =	0.0610	61 023	35.314	1.308
2 =	0.1220	122 047	70 629	2.616
3 =	0.1831	183 070	105 943	3 924
4 =	0.2441	244.094	141.258	5 232
5 =	0.3051	305.117	176 572	6.540
6 =	0.3661	366 140	211 887	7.848
7 =	0.4272	427.164	247 201	9 156
8 =	0 4882	488 187	282 516	10.464
9 =	0 5492	549 210	317 830	11.771

Capacity.

	Millilitres or Cubic Centimetres to Fluid Drams.	Centilitres to Fluid Ounces.	Litres to Quarts.	Decalitres to Gallons.	Hectolitres to Bushels.
1 =	0.27	0.338	1.0567	2.6417	2.8377
2 =	0.51	0.676	2.1134	5.2834	5.6755
3 =	0.81	1.014	3.1700	7.9251	8.5132
4 =	1.08	1.353	4.2267	10.5668	11.3510
5 =	1.35	1.691	5.2834	13.2085	14.1887
6 =	1.62	2.029	6.3401	15.8502	17.0265
7 =	1.89	2.367	7.3968	18.4919	19.8642
8 =	2.16	2.705	8.4535	21.1336	22.7019
9 =	2.43	3.043	9.5101	23.7753	25.5397

Weight.

	Milligrammes to Grains.	Kilogrammes to Grains.	Hectogrammes to Ounces Avoirdupois	Kilogrammes to Pounds Avoirdupois.
1 =	0.01543	15432.36	3.5274	2.20462
2 =	0.03086	30864.71	7.0548	4.40924
3 =	0.04630	46297.07	10.5822	6.61387
4 =	0.06173	61729.43	14.1096	8.81849
5 =	0.07716	77161.78	17.6370	11.02311
6 =	0.09259	92594.14	21.1644	13.22773
7 =	0.10803	108026.49	24.6918	15.43236
8 =	0.12346	123458.85	28.2192	17.63698
9 =	0.13889	138891.21	31.7466	19.84160

Weight—(*Continued*).

	Quintals to Pounds Avoirdupois.	Milliers or Tonnes to Pounds Avoirdupois.	Kilogrammes to to Ounces Troy.
1 =	220.46	2204.6	32.1507
2 =	440.92	4409.2	64.3015
3 =	661.39	6613.9	96.4522
4 =	881.85	8818.5	128.6030
5 =	1102.31	11023.1	160.7537
6 =	1322.77	13227.7	192.9044
7 =	1543.24	15432.4	225.0552
8 =	1763.70	17637.0	257.2059
9 =	1984.16	19841.6	289.3567

The nautical mile of the U. S. Coast and Geodetic Survey is defined as the length of one minute of arc of a great circle of a sphere, the surface of which is equal to that of the earth.

1 nautical mile = 6080.198 feet = 2026.7327 yards.

4. METRIC SYSTEM.

The unit was originally derived from the measurement of 1 degree latitude. From this measurement the standard metre, defined to be the one ten-millionth $\left(\frac{1}{10000000}\right)$ part * of one quarter of a meridian, was constructed. It is known as the "METRE DES ARCHIVES." From this all other units of measurement of surface, of volume, and of weight are derived as follows:

LAND SURFACE.

Are: The surface of a square of 10 metres side = 100 square metres.

Hectare = 100 ares = 10000 square metres.

LIQUID AND DRY MEASURES.

Dry (for cereals, wood, stone, etc.)

Litre: The contents of a cubic decimetre or of a cube $\frac{1}{10}$ metre side.

Hectolitre: One hundred litres, $\frac{1}{10}$ of a cubic metre.

Stere: One cubic metre.

WEIGHT.

Gramme: The weight of 1 centimetre cube of distilled water at its maximum density at a temperature of 3.94° C. = 39.1° F

Kilogramme: The weight of 1 litre of distilled water at maximum density.

Tonne: One thousand kilogrammes. Weight of 1 metre cube of distilled water at maximum density.

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* One quarter meridian measures 10,001,900 metres by later determinations.

METRIC-SYSTEM MULTIPLES AND SUBDIVISIONS

	Measure of	Length	Surface	Volume	Weight	
	Unit	Metre	Are	Litre	Gramme	Kilogramme
Multiples.	10 units*	Decametre		Decalitre	Decagramme	
	100 "	Hectometre	Hectare	Hectolitre	Hectogramme	Quintal
	1000 "	Kilometre		Stere	Kilogramme	Tonne
	10000 "	Myriametre		Decastere		
Subdivision.	0.1 units	Decimetre	Deciare	Decilitre	Decigramme	Hectogramme
	0.01 "	Centimetre	Centiare	Centilitre	Centigramme	Decagramme
	0.001 "	Millimetre	Milliare	Millilitre	Milligramme	Gramme

5. CUSTOMARY MEASUREMENTS OF THE UNITED STATES.

MEASURES OF LENGTH AND SURFACE

Length	Inches	Feet	Yards	Rods	Furlongs	Mile (Land)
Foot	12	1				
Yard	36	3	1			
Rod	196	16½	5½	1		
Furlong	7920	660	220	40	1	
Mile (land)	63360	5280	1760	320	8	1
Mile (nautical)		6080.198	2026.733			
Gunter's chain	792	66	22	4	0.1	1/80
Link (100 per chain)	7.92	0.66	0.22			
Cable		720	120			
Fathom		6	2			
Surface	**Square Inches**	**Square Feet**	**Square Yards**	**Square Rods**	**Square Roods**	**Acres**
Square foot	144	1				
Square yard	1296	9	1			
Square rod		272.25	30.25	1		
Square rood		10890	1210	40	1	
Acre		43560	4840	160	4	1
Square mile			3097600	102400	2560	640

MEASURES OF VOLUME.

Volume	Minims	Drachms	Ounces Fluid	Pints Liquid	Pints Dry	Quarts Liquid	Quarts Dry	Gallons Liquid	Gallons Dry	Peck, Dry
1 Drachm . .	60									
1 Fluid ounce	480	8								
1 Pint. .	7680	128	16	1						
1 Quart. . .	15360	256	32	2	2	1				
1 Gallon. . .	61440	1024	128	8	8	4	4	1		
1 Peck. . .				18.618	16	9.309	8	2.327	2	1
1 Bushel.				71.472	64	37.236	32	9.309	8	4

The **standard gallon** contains 231 cubic inches. Its contents of distilled water at maximum density at a temperature of 3.93° C = 39.07° F. and mean atmospheric pressure of 30 inches = 762 mm. weigh 3.78543 kgm = 8.31518 pounds avoirdupois.

The **standard bushel** is of 2150.42 cubic inches Its contents of distilled water at maximum density weigh 35.239 kgm. = 77.6885 pounds avoirdupois Inside dimensions: diameter 18.5″, height 8″. Heaped, the cone should be 6″ high.

BUSHELS IN POUNDS AVOIRDUPOIS

(Commercial.)

Substance	Pounds per Bushel	Substance	Pounds per Bushel
Corn, shelled.	56	Land plaster.	100
Cement.	80	Lime, unslaked.	80
Coke.	40	Lime, slaked.	40
Charcoal.	22	Potatoes.	60
Coal stone.	80	Wheat.	60

MEASURES OF WEIGHT.

Avoirdupois	Troy Grains	Drachms	Ounces	Troy Pounds	Avoir. Pounds	Hundred-weight, cwt.
1 Ounce	437.5	16				
1 Pound, lb.	7000	256	16	1.2153	1	
1 Hundredweight, cwt					112	1
1 Ton, long.					2240	20
1 Ton, short.					2000	

Troy	Troy Grains	Penny-weight, dwt.	Ounces	Pounds, Avoir-dupois
1 Pennyweight, dwt. .	24			
1 Ounce	480	20	1	
1 Pound. . .	5760	240	12	0.82286

MEASURES OF WEIGHT.—(*Continued*)

APOTHECARIES'	Troy Grains	Scruples	Drachms	Ounces	
1 Scruple, W	20				
1 Drachm, W	60	3			
1 Ounce, W	480	24	8		
1 Pound, W	5760	288	96	12	

DIAMONDS	Carats	Grains	Parts	Gramme	Grains Troy
1 Gramme	4 875	19 5	312		15.432
1 Carat	1	4	64	0 20512	3.17

MEASURES OF VALUE.

Denominations	Mills	Cents	Dimes	Dollars	Eagles
1 Cent	10	1			
1 Dime	100	10	1		
1 Dollar	1000	100	10	1	
1 Eagle	10000	1000	100	10	1

6. WEIGHT OF U. S. COINS

Standard and Pure Metal.—Standard gold and silver: 9 parts of pure gold or silver and 1 part of alloy, generally copper.

Commercial abbreviations: $ = Dollar, c = Cents.

Gold Coins		Standard Gold		Pure Gold	
Name	$	Grammes	Troy Grains	Grammes	Troy Grains
Dollar	1	1.672	25.8	1 5046	23.22
Quarter-eagle	2½	4 179	64.5	3 7616	58.05
Three dollars	3	5.0154	77.44	4 5139	69.66
Half-eagle	5	8 359	129	7.523	116.1
Eagle	10	16 72	258.	15 046	232.2
Double-eagle	20	33.436	516.	30.092	464.4

Silver Coins		Standard Silver		Pure Silver	
Name	C	Grammes	Troy Grains	Grammes	Troy Grains
Dime	10	2.5	38.58	2 25	34.722
20 cents	20	5	77.16	4 5	69.444
Quarter	25	6 25	96 45	5.625	86.805
Half-dollar	50	12 5	192.9	11.25	173.11
Dollar	100	26.73	412.5	24.06	371.25

7. Fineness of Gold Expressed in English Trade System.

(Quantities in vertical columns are equivalent.)

Assay pound.	1				
Carat	24	1			
Carat grains.	96	4	1		
Eighth	768	32	8	1	
Excess grains.	5760	240	60	7 5	1
Per cent.	100	4 167	1 042	0.130	0.0174
Per thousand.	1000	41 667	10.417	1.302	0.174

The standard of fineness for English gold coin is 11 parts fine gold, 1 part copper 22 carat fine or 916 667 parts of fine gold in 1000 parts of gold and copper alloy, and 83.333 copper. Specific gravity, 17.157.

8. VALUES OF FOREIGN COINS.

(From U. S. Treasury Report, 1902.)

A.—Countries with Fixed Currencies.

Countries	Standard	Monetary Unit	Value in U S Gold	Coins
Argentine R.	G. & S.	Peso	$0 96,5	Gold argentine ($4.82,4) and ½ argentine; silver—peso and divisions
Austria-Hungary	Gold	Crown	20,3	Gold—20 crowns ($4.05,2) and 10 crowns.
Belgium.	G. & S.	Franc	.19,3	Gold—10 and 20 franc pieces; silver—5 francs.
Brazil.	Gold	Milreis	.54,6	Gold—5, 10, and 20 milreis; silver—½, 1, and 2 milreis.
British N. A. (except Newfoundland).	Gold	Dollar	1.00	
British Honduras	Gold	Dollar	1.00	
Chile.	Gold	Peso	.36,5	Gold—escudo ($1.25), doubloon ($3.65), and condor ($7.30); silver—peso and divisions.
Costa Rica.	Gold	Colon	.46,5	Gold—2, 5, 10, and 20 colons; silver—5, 10, 25, and 50 centisimos.
Cuba.	G. & S.	Peso	.92,6	Gold—doubloon ($5.01,7); silver—peso (60 cents).
Denmark.	Gold	Crown	.26,8	Gold—10 and 20 crowns.
Ecuador.	Gold	Sucre	.48,7	Gold—10 sucres ($4.8665); silver—sucre and divisions.
Egypt.	Gold	Pound (100 piasters)	4 94,3	Gold—10, 20, 50, and 100 piasters; silver—1, 2, 10, and 20 piasters
Finland.	Gold	Mark	.19,3	Gold 10 and 20 marks ($1.93 and $3 85,9)
France.	G. & S.	Franc	19,3	Gold—5, 10, 20, 50, and 100 francs; silver—5 francs.

A.—Countries with Fixed Currencies—*Continued.*

Countries	Standard	Monetary Unit	Value in U.S. Gold	Coins
Germany ..	Gold	Mark	$0 23,8	Gold—5, 10, and 20 marks
Great Britain	Gold	Pound sterling	1 86,6½	Gold—sovereign (pound sterling) and half sovereign
Greece...	G. & S.	Drachma	19,3	Gold—5, 10, 20, 50, and 100 drachmas; silver—5 drachmas.
Haiti....	G. & S.	Gourde	96,5	Silver—gourde
India....	Gold	Rupee	32,4	Gold—sovereign ($4 8665); silver—rupee and divisions.
Italy....	G. & S.	Lira	19,3	Gold—5, 10, 20, 50, and 100 lire; silver—5 lire.
Japan....	Gold	Yen	49,8	Gold—1, 2, 5, 10, and 20 yen.
Liberia...	Gold	Dollar	1 00	
Netherlands	G. & S.	Florin	40,2	Gold—10 florins; silver—½, 1, and 2½ florins.
Newfoundland	Gold	Dollar	1 01,4	Gold—$2 ($2 02,7).
Peru....	Gold	Sol	.48,7	Gold—libra ($4 8665); silver—sol and divisions
Portugal...	Gold	Milreis	1 08	Gold—1, 2, 5, and 10 milreis.
Russia...	Gold	Ruble	.51,5	Gold—imperial ($7.718) and ½ imperial ($3.80), silver—¼, ½, and 1 ruble.
Spain..	G. & S.	Peseta	.19,3	Gold—25 pesetas; silver—5 pesetas.
Sweden and Norway	Gold	Crown	.26,8	Gold—10 and 20 crowns.
Switzerland	G. & S.	Franc	.19,3	Gold—5, 10, 20, 50, and 100 francs; silver—5 francs.
Turkey..	Gold	Piaster	04,4	Gold—25, 50, 100, 200, and 500 piasters
Uruguay...	Gold	Peso	1 03,4	Gold—peso; silver—peso and divisions.
Venezuela..	G. & S.	Bolivar	19,3	Gold—5, 10, 20, 50, and 100 bolivars; silver—5 bolivars.

B.—Countries with Fluctuating Currencies.

Countries	Monetary Unit	Values in U. S. Gold (Cents) from 1899 to 1902		
		Highest	Lowest	Average
Bolivia........	Silver boliviano	46 8	38 2	42 5
Central America..	Silver peso	46 5	38 2	42.4
China........	Tael *..	77 1	56 5	66.3
Columbia........	Silver peso	46 8	38 2	42 5
Mexico..........	Silver dollar..	50 9	41 5	46 2
Persia...........	Silver kran...	8 6	7 0	7.8

* The tael varies in value in the different provinces of China.

9. DYNAMIC MEASUREMENTS.

Dynamic Quantities	Customary U. S. Units	Equivalent in Metric Units
Speed	Foot per second	0.3048 mtrs per send
Force	Pound	0.4536 klgm
Pressure, stress	Pound per sq in.	0.0703 klgm per cm^2
Work	Foot-pound	0 138 klgm-mtrs
Power	Ft-pnd per send	0 138 klgm-mtr pr send
Horse power	550 ft-pdns per send	176 038 klgm mtr per send
" "	33000 ft-pnds per minute	1568 28 klgm-mtr per min.

Dynamic Quantities	Metric Units	Equivalent in Customary U. S Units
Speed	Metre per second	3 28 feet per second
Force	Kilogramme	2.2046 pounds
Pressure, stress	Klgm pr cm^2	14.234 pnds pr in^2
Work	Klgm-metre	7 232 foot-pnds
Power	Klgm-metre per send	7 232 ft-pnds per send
Horse-power	75 klgm mtr per send	542 39 ft-pnds send
" "	4500 klgm mtr per min	32543.4 ft-pnds pr minute

Definitions and Abbreviations: Pnd pr in^2 is pounds pressure per square inch of surface, and klgm per cm^2 means kilogrammes per square centimetre of surface, or in the case of stresses it means pounds per square inch of section or kilogrammes per square centimetre of sectional area.

Foot-pound, ft-pnd: One pound lifted one foot high.

Kilogramme-metre, klgm-mtr: One kilogramme lifted one metre high; generally, the work necessary to move a resistance equivalent to a unit of the force of gravity through unit space

Ft-pnd per send: The work of one foot-pound performed in one second of time

Klgm-mtr per send: The work of one kilogramme-metre performed in one second.

Ft-pnds-min: Foot-pounds per minute.

Klgm-mtr per min: Kilogramme-metre per minute.

10. THERMODYNAMIC MEASUREMENTS.

Temperature is measured by the effect of heat in expanding various substances, as mercury, alcohol, air, and various combinations of metals.

The variation of resistance to the flow of an electric current has been used for measuring very high temperatures.

Thermometers are instruments for the indication at relatively moderate temperatures.

Pyrometers are used for very high temperatures.

The graduations of all thermometers are based on the freezing- and on the boiling-points of distilled water at normal atmosphere, equivalent to a pressure of a barometric column of mercury at freezing-point of 76 cm, or about 29.92 inches in height.

The thermometers consist of a closed glass tube of some length with a very fine, usually flat, tubular hole of even cross-section throughout its whole length (calibrated tube), and a bulb of some volume containing the mercury or other liquid, which extends partially into the flat tubular hole and in which it can expand or contract sufficiently to indicate the extremes of heat or cold.

Customary Thermometers.

Centigrade, indicating degrees C., in which the linear expansion of the indicating liquid in the tube, between freezing- and boiling-point of distilled water, is divided into 100 equal parts, each of which is called one degree C. (1° C.), the freezing-point being 0° C., the boiling-point 100° C.

The Fahrenheit, in which the same amount of linear expansion is divided into 180 equal parts, the freezing-point being designated by 32° F., and the boiling-point by 212° F. = 180° + 32°

The Reaumur, in which the freezing-point is designated by 0° R, and the boiling-point of the distilled water by 80° R.

Equivalents of the Different Degrees of Thermometers.—If n = number of degrees, to be positive (+) when above, and negative (−) when below 0°, and C, F and R. for Centigrade, Fahrenheit, and Réaumur degrees, then:

$$n^\circ\ \mathrm{C} = (\tfrac{9}{5}n+32)^\circ\ \mathrm{F} = (1.8\times n+32)^\circ\ \mathrm{F}$$

$$n^\circ\ \mathrm{C} = (\tfrac{4}{5}\times n)^\circ\ \mathrm{R} = (0.8\times n)^\circ\ \mathrm{R}$$

$$n^\circ\ \mathrm{F.} = (\tfrac{5}{9}(n-32))^\circ\ \mathrm{C} = (0.555\times(n-32))^\circ\ \mathrm{C.}$$

$$n^\circ\ \mathrm{F.} = (\tfrac{4}{9}(n-32))^\circ\ \mathrm{R} = (0.444.\ (n-32))^\circ\ \mathrm{R.}$$

$$n^\circ\ \mathrm{R.} = (\tfrac{5}{4}n)^\circ\ \mathrm{C} = (1.25n)^\circ\ \mathrm{C.}$$

$$n^\circ\ \mathrm{R.} = (\tfrac{9}{4}n+32)^\circ\ \mathrm{F.} = (2.25n+32)^\circ\ \mathrm{F.}$$

Quantity of Heat.

Calorie: One kilogramme of distilled water at its temperature of maximum density of 4° C. heated to 5° C. will absorb one metric unit quantity of heat.

Calorie Gramme: The quantity of heat absorbed by one gramme of distilled water when heated 1° C., from 4° C. to 5° C.

British Thermal Unit, B.T.U.: The quantity of heat necessary to heat 1 pound of distilled water from the temperature of 39.2° F. one degree F.

1 Calorie = 3.9683 B.T.U.
1 B.T.U. = 0.252 Calorie.

11. Electric Units.—The electromagnetic units by the British Association, and ratified by the Congress of Electricians held in Paris in 1881 and in Chicago, U. S., in August, 1893

Time: 1 *second*, designated by S.

Length: 1 *centimetre*, designated by C.

Mass: 1 *gramme*, designated by G.

C.G.S. Units: Centimetre, Gramme, Second Units.

Speed: 1 *centimetre* in 1 *second*.

Force: 1 *dyne*, the force acting during 1 second on the mass of 1 gramme and producing an acceleration of speed of 1 centimetre per second. This acceleration in Paris is $\frac{1}{981}$ part of that produced by gravity.

Work: 1 *erg*, the work of moving a body 1 centimetre against a resistance of 1 dyne.

Power: 1 *erg* in 1 *second*.

Heat: The C.G.S. heat unit; the quantity of heat produced by 1 erg of work or equivalent to it.

Magnetic Force: The *unit magnetic pole*, the C.G.S. unit of magnetism. The force which causes two similar magnetic poles to repulse each other to a distance of 1 centimetre by a force of 1 dyne.

Current Density: The C.G.S. unit of current density; the current in a conductor of 1 centimetre in length bent to a radius of 1 centimetre producing at the centre a force of 1 dyne when acting on a unit pole of magnetism.

Current Quantity: The C.G.S. unit of current density passing in an electrical circuit in 1 second.

Electromotive Force or Potential: The difference of potential

(pressure) between two points of a conductor producing an erg of work by a C.G.S unit of current density.

Resistance: The resistance of a conductor requiring a C.G.S. unit difference of potential between its extremities for the production of a C.G.S. unit of current

Capacity: The capacity of a condenser which will hold a C.G.S unit quantity of electricity with a unit potential difference between its terminals.

11a. Practical Units by the International Congress on Electrical Units, Chicago, Aug. 1893.

Resistance: *International Ohm:* The resistance of a column of pure mercury, weighing 14.4521 grammes, of 1 square millimetre section and 106.3 centimetres length at 0° C = 32° F. The international ohm is equal to 10^9 times the C.G.S. unit of resistance.

Electromotive Force, or Potential: *Volt:* The electromotive force (pressure or tension) necessary to maintain an electric current density of one ampere current $= \frac{1}{10}$ C.G.S. unit current in a conductor of 1 ohm resistance The volt is equal to 10^8 the C.G.S unit of electromotive force

Current Density, Current Strength: *Ampere:* The current density or strength maintained in a conductor of 1 ohm of resistance by an electromotive force or electric tension of 1 volt.

One ampere is equal to 10^{-1} or $\frac{1}{10}$ the C G.S. unit of current density.

Current Quantity: *Coulomb:* The quantity of electricity of one ampere current strength in one second. It is equal to 10^{-1} or $\frac{1}{10}$ of a C.G.S. current quantity.

One coulomb will decompose 0.0935 milligramme of water in one second from acidulated water in a voltmetre. It will deposit from a salt of copper solution 0.3286 milligramme of copper, and from a salt of silver solution 1.118129 milligrammes of silver.

Capacity: *Farad:* The capacity of a condenser retaining one coulomb of electric quantity at an electric tension of 1 volt.

One farad is equal to 10^{-9} times the C.G.S. unit of capacity.

Magnetic Force: The C.G.S. unit of magnetic force of one dyne at the centre of curvature of a conducting wire of 1 centimetre in length bent into an arc of a circle of 1 centimetre radius, through which passes a current of C.G.S. unit density or of 10 amperes.

A conducting wire bent into a circle of 10 centimetres diameter with a current of $\frac{10\times 25}{10\times\pi}=7.9578$ amperes produces at the centre of curvature through air or a non-magnetic substance also a unit magnetic pole of one dyne If a magnetic substance is substituted for the air the magnetic force is greatly multiplied, the multiplication depending on the magnetic substance and on the degree of magnetization.

Magnetizing Force: *Line of Force, Maxwell:* The magnetic force radiating from a unit pole of one dyne at the distance of 1 centimetre through every centimetre square of a spherical surface enclosing the unit pole The surface of such a sphere of 1 centimetre radius being $4\pi=12.5664$ cm.^{2}, this number of lines of force therefore radiate from a unit pole.

Ampere-turn: One ampere current making one turn, or one half ampere current making two turns, etc.

A solenoid of one square centimetre sectional area, with an exciting power of one ampere electric current density for each centimetre length of the solenoid (one ampere-turn per cm.), will have at its extremities magnetic poles of $\frac{1}{10}=0.1$ unit strength, from which will radiate $\frac{4\pi}{10}=1.257$ *Maxwell's or lines of force* in air.

If, for instance, pure soft iron be substituted for the air, then the lines of force may be multiplied from 3000 to 4000 times for a moderate magnetization, according to some authorities.

Work: *Joule:* The C.G.S. unit of work multiplied by 10^7 or 10^7 ergs $=\frac{100}{981}$ kilogramme-metres $=0.10193$ kilogramme-metre, which is equivalent to 0.73726 foot-pound.

Power: *Watt*, one *volt-ampere in one second or* one *joule in one second:* The power necessary to maintain one volt electromotive force in a conductor carrying a current density of one ampere.

One watt $=10^7$ ergs per second $=0.10193$ klgm-metre $=0.73726$ ft-pound per second $=6.1158$ klgm-metres $=44.2456$ ft-pounds per minute.

Horse-power: Electric horse-power equal to 746 watts.

The metric horse-power of 75 kilogramme-metres per second is equal to 735.75 watts.

One foot-pound per second = 1.356 watts.

One kilogramme-metre per second is equal to 9.81 watts.

Multiples: Decimal multiples of units are expressed by deka, ten times; hecto, one hundred times; kilo, one thousand times; mega, one million times. For instance, kilowatts, one thousand watts; meg ohms, one million ohms.

Parts or Fractions: Decimal fractions of units are expressed by deci, one tenth; centi, one hundredth; milli, one thousandth; micro, one millionth A microfarad is one millionth of a farad.

11b. Photometry or Measuring of the Intensity of Light.—**British Unit:** The British light unit is the intensity of light from a spermaceti candle ⅞″ in diameter burning 120 grains per hour (6 candles to the pound)

French Unit: The light of a carcel lamp from a flame 40 mm. high burning 42 grammes pure colza oil per hour The light from a carcel lamp used as unit is equivalent to the light of 9.5 British standard candles.

German Unit: The light of a paraffin candle 20 mm. in diameter, the flame being 5 cm. high.

The bec-carcel is equivalent to 7.6 German candles.

12. GEOLOGIC CLASSIFICATION OF ROCK STRATIFICATIONS,

based on remains of former living organisms found in them

Rocks or mineral stratifications are in consequence considered to be of the

I. Azoic or **Archæn Time,** the lifeless age.

II. Paleozoic or **Primary Time,** subdivided into the

1. **Cambrian,** or **Crustacean.**
2. **Silurian,** or **Mollusk.**
3. **Devonian,** or **Fish.**
4. **Carboniferous,** or **Coal Plant Age.**

III. Mesozoic or **Secondary Time** or **Reptilian Age.**

IV. Cenozoic or **Tertiary Time** or **Mamalian Age.**

V. Post-tertiary or **Quaternary** or **Human Era.**

MINERAL FORMATIONS AND ROCKS.

I. Azoic. Granite, syenite, gneiss, hornblende, mica schist, chloridic and talcose schists, marble, graphite, etc.

II. Paleozoic. **1. Cambrian:** Slates, grits, sandstones, conglomerates, shales, quartz rock, schists.

2a. Lower Silurian: Magnesian limestone, sandstone, slate,

limestone, shales, shaly sandstone, pebbly grit, conglomerate, graywacke.

2b. Upper Silurian: Conglomerates, shaly sandstones, limestone, hard slate, grits.

3. Devonian: Sandstone, conglomerate, grit, graywacke, limestone, shales, shaly or thinly bedded limestone and sandstone

Ores of iron, lead, tin, copper; etc., petroleum in sandstone is found in Devonian rock.

4. Carboniferous: Limestone massive, often oolitic, sometimes dolomitic, often with nodules of flinty chert; sandstones from very fine to pebbly; stratified shales with coal-seams underlaid with clay shales; clay-iron stones in beds, layers, or nodular concretions.

III. Mesozoic. **1. Triassic:** Sandy clay, sandstone, shale, impure limestone, dolomite, marl.

2. Jurassic: Repeated succession of argillaceous, arenaceous, and calcareous layers, oolite

3. Cretaceous: Sands, sandstones, clay bands, calcareous strata passing into white chalk, limestone, phosphatic nodules, chalky marl, argillaceous chalk, bituminous limestones, carbonaceous shales, and clay

IV. Cenozoic. **1. Eocene:** Nummulitic limestone, sandstone, clay, marl, calcareous sandstones

2. Oligocene: Sand, clay, marl, and limestone, alternating in thin beds, gypsum, silicious sandstone, conglomerate, lignite.

3. Miocene: Breccia of shells and shell fragments, sometimes mixed with sand or passing into a more compact calcareous mass and now and then into limestone, clay, sand, marl.

4. Pliocene: Shelly sands and marls, shelly gravel and conglomerate, peat beds, clay, limestone, soft sandstone

V. Post-tertiary. **1. Pleistocene:** Post-Pliocene, or Diluvial; Ice Age rocks with smooth-grooved surfaces ground by ice.

2. Recent or **Human Period:** River alluvia sand, brick earth, rocks, and mineral beds containing implements made by man.

13. EARTH.

Circumference of the Earth, 40,000 kilometres.
25,000 miles, about.
21,600 nautical miles.

Diameter at Equator, 12,752 5 kilometres = 7926 miles.

Diameter at Poles, 12,731 4 kilometres = 7912¾ miles

Part of earth's surface covered by salt water or **Oceanic Basin** = $\frac{8}{11}$ of the whole surface

Continents or continental plateaus, dry land = $\frac{3}{11}$ of the surface of earth

The greatest **Depth of the Ocean** below water-level reaches probably 50,000 ft

Depth across the **telegraphic plateau** from **Newfoundland** to **Ireland,** from 10,000 to 15,000 ft

Mean depth of the **Pacific Ocean** between **Japan** and **San Francisco,** as determined by Professor Bache in 1855, about 13,000 ft

Height of **atmospheric air,** 40 to 45 miles.

Highest Mountain measured:

Mount Everest in the **Himalayas,** 29,000 ft. Mean height of **Europe,** 670 ft ; **Asia,** 1150 ft ; **North America,** 748 ft.; **South America,** 1132 ft.; **Africa,** probably 1600 ft ; **Australia,** perhaps 500 ft.

14. CONSTITUTION OF ROCKS.

Quartz, or **Silica:** One of the most abundant and hardest minerals. Does not melt before the blowpipe and does not dissolve in water

Quartz crystallizes generally in hexagonal prisms with pyramid ends and in other crystalline systems Color, when pure, transparent, colorless.

Silica ordinarily milky, reddish, yellowish, brownish, and rarely black. Fracture conchoidal without cleavage

Silica secreted by animal species.

Silica spicules by sponges. Silicious shells by microscopic forms, polycystines, and by microscopic plants, diatoms.

Chemically, silica is a combination of silicon and oxygen, Si_2O_3. Silicates are combinations of silica with alumina, magnesia, lime, potash, soda, oxids of iron and other oxids.

Alumina, when pure and crystallized as in **sapphire** and corundum, is the second hardest substance It is infusible and insoluble in water. A rock-like variety is used as *emery*

Magnesia, infusible and insoluble, as hard as quartz when crystallized.

Lime, potash, and soda and also oxid of iron, form fusible combinations with silica.

Feldspar, double silicate of alumina and lime, of alumina and potash or of alumina and soda. Common feldspar, or orthoclase, is mainly a double silicate of alumina and potash.

Feldspar, named **Albite,** double silicate of alumina and soda. **Labradorite,** double silicate of alumina and lime. Fracture, cleavage structure in two directions with flat and shining surfaces Hardness about equal to quartz. Color: Albite, usually white; labradorite, often brownish; other kinds sometimes flesh-red.

Mica is also a double silicate of alumina and of potash, lime, magnesia, or oxid of iron. Cleaves into very thin, tough leaves. Color transparent, some milky, brownish, and black.

Hornblende and **Pyroxene,** a combination of silica, magnesia, lime, and protoxid of iron. Hornblende often occurs in slender needle-shaped crystals called asbestos when fibrous. Color dark green, greenish black, and black, sometimes gray and white. Cleavable. Hardness similar to feldspar, fusibility greater. Specific gravity = 3 to 3.5.

Garnet, in crystals, dodecahedrous or trapezohedrous, disseminated in rocks.

Tourmaline, in prismatic crystals of 3, 6, 9, or 12 surfaces, generally imbedded in gneiss and mica schists, sometimes in quartz.

Talc and **Serpentine:** Silica, magnesia, and water.

Talc, Soapstone, or **Steatite:** Very soft. Color pale green.

Serpentine: Harder than talc; can be carved with a knife. Color dark green, texture fine-grained.

Carbon in its pure state and crystallized is the **diamond,** the hardest known substance.

Graphite, or **Black Lead:** Soft and friable.

Charcoal is carbon combined with a small portion of ashes of various composition, according to the organic source from which it is derived.

Bituminous Coals are combinations of carbon, hydrogen, and some oxygen with more or less silica, alumina, lime, iron, sulphur, and other substances constituting the ashes of a great variety of compositions left after combustion.

Anthracite Coals are carbon combined with a variety of substances left after combustion as ashes.

Carbon in burning combines with oxygen, forming, when the combustion is complete, carbonic acid or dioxid of carbon, CO_2.

Carbonate of Lime, or Calcite, is a combination of lime and carbonic acid. It crystallizes in various forms, especially as a rhombohedron. Cleaves in three directions with shining surfaces. Hardness: can be scratched with a knife. It is decomposed by acids, especially hydrochloric and sulphuric, with liberation of carbonic acid. It is also decomposed by heat (bright-red or white) in a kiln or by a blowpipe, and is thereby converted into caustic lime or quicklime.

Dolomite, or Magnesian Limestone, is a double carbonate of lime and magnesia. It is decomposed by acids when heated.

15. BEAUMÉ'S HYDROMETER.

Degrees of liquids heavier and lighter than water and corresponding specific gravities at 0° C.

Baumé Degree	Specific Gravity of Liquids		Baumé Degree	Specific Gravity of Liquids		Baumé Degree	Specific Gravity of Liquids	
	Heavier than Water	Lighter than Water		Heavier than Water	Lighter than Water		Heavier than Water	Lighter than Water
0	1.000		26	1.206	0.901	52	1.520	0.777
1	1.007		27	1.216	0.896	53	1.535	0.773
2	1.013		28	1.226	0.890	54	1.551	0.768
3	1.020		29	1.236	0.885	55	1.567	0.764
4	1.027		30	1.246	0.880	56	1.583	0.760
5	1.034		31	1.256	0.874	57	1.600	0.757
6	1.041		32	1.267	0.869	58	1.617	0.753
7	1.048		33	1.277	0.864	59	1.634	0.749
8	1.056		34	1.288	0.859	60	1.652	0.745
9	1.063		35	1.299	0.854	61	1.670	
10	1.070	1.000	36	1.310	0.849	62	1.689	
11	1.078	0.993	37	1.322	0.844	63	1.708	
12	1.086	0.986	38	1.333	0.839	64	1.727	
13	1.094	0.980	39	1.345	0.834	65	1.747	
14	1.101	0.973	40	1.357	0.838	66	1.767	
15	1.109	0.967	41	1.369	0.825	67	1.788	
16	1.118	0.960	42	1.382	0.820	68	1.809	
17	1.126	0.954	43	1.395	0.816	69	1.831	
18	1.134	0.948	44	1.407	0.811	70	1.854	
19	1.143	0.942	45	1.421	0.807	71	1.877	
20	1.152	0.936	46	1.434	0.802	72	1.900	
21	1.160	0.930	47	1.448	0.798	73	1.924	
22	1.169	0.924	48	1.462	0.794	74	1.949	
23	1.178	0.918	49	1.476	0.789	75	1.974	
24	1.188	0.913	50	1.490	0.785	76	2.000	
25	1.197	0.907	51	1.505	0.781			

If for 0° Bé = 0° Twaddell the specific gravity = 1000, then specific gravity for x° Twaddell = 1000 + 5x.

16. ATOMIC WEIGHTS OF ELEMENTARY SUBSTANCES, with some chemical and physical data.

	Substance	Symbol	Valency	Atomic Weights		Electrolyte	Electro-chemical Equivalent Deposited by One Coulomb	Specific Gravity	Melting point, Degree C.	Boiling point, Degree C.
				Oxygen =16	Hydrogen =1		milligrams			
1	Aluminium......	Al	3	27 11	26 93	Oxids and oxid salts	0 093541	2 7	650	
2	Antimony.......	Sb	3–5	120.43	119.7	Sulpho salts	0 415361	6 7	440	
3	Argon..........	A		39 96	39					
4	Arsenic.........	As	3–5	75 01	74.81	Arsenites	0 258975	5.88		
5	Barium.........	Ba	2–4	137 43	137 09	Haloid salts	0 709798	3.95	1200	
	Beryllium [1].									
6	Bismuth.........	Bi	3–5	208 9	203 39	Oxid salts	0.718258	9 76	267	
7	Boron..........	B	3	11	10 97					
8	Bromin.........	Br	1–3–5–7	79 95	79 75	Bromids	0 828336			
9	Cadmium........	Cd	2	112 4	111.72	Salts	0.580518	8.7	320	850
10	Cæsium.........	Cs	1	132 9	132 57					
11	Calcium.........	Ca	2	40 1	39 9	Haloid salts	0.207180	1.6	900	
12	Carbon.........	C	2–4	12	11 97					
13	Cerium.........	Ce	4	139	138 44			6.7	800	
14	Chlorin.........	Cl	1–3–5–7	35.46	35 34	Chlorids	0 367257			−35
15	Chromium.......	Cr	2–3–4–6	52.14	51.97	Chromous } salts Chromic } salts	0.270105 0 180070	6.7		
16	Cobalt..........	Co	2–4	59	58.85	Cobaltous salts	0 308479	8.54		
17	Columbium [2].....	Cb or Nb	3–5	93 73	93.45					
18	Copper	Cu	1–2	63.60	63.44	Cuprous } salts Cupric } salts	0.657175 0 328567	8.94	1050	3000
	Didymium [3].....	Di		142 12	141.77			6.5		
19	Erbium.........	Er	3	166 3	165 88					
20	Fluorin.........	F	1	19 06	18.95	Fluorids	0.196727			
21	Gadolinium......	Gd	1–3	156.76	155.71					

[1] Beryllium = Glucinium. [2] Columbium = Niobium. [3] Didymium is now split into Neodymium and Praseodymium.

22	Gallium.	Ga	3	69.91	69 7					
23	Germanium.	Ge	4–2	72 5	72 12					
24	Glucinium [1]	Gl or Be	2	9.08	8 98			1.64	800	
25	Gold.	Au	3–1	197.23	196 81	Haloid salts	0.681104	19.3		
26	Helium.	He			4 0					
27	Hydrogen.	H	1	1.003	1	Acid water	0.010392			
28	Indium.	In	3	113 85	113 5					
29	Iodin.	I	1–3–5–7	126 85	126 53		1.314184			
30	Iridium.	Ir	2–3–4	193 12	192 62			22.4	1988	
31	Iron.	Fe	2–3–4	56	55.86	Ferrous salts Ferric salts	0.298052 0.193368	7.86	2000	
32	Krypton.	Kr		82	81 8					
33	Lanthanum	La	3	138 6	137 85			6 1	850	
34	Lead.	Pb	2–4	206 92	206 43	Oxids and salts	1 071695	11.44	334	
35	Lithium.	Li	1	7.03	7	Haloid salts	0 072823			
36	Magnesium.	Mg	2	24 3	24 24	Haloid salts	0 126276	1 75	650	1100
37	Manganese.	Mn	2–4–7	55	54 86	Manganous salts	0.285338	8	1400 ?	
38	Mercury.	Hg	1–2	200	199 5	Mercurous salts Mercuric salts	2 075943 1.037972	13 59	−39 4	360
39	Molybdenum. . . .	Mo	2–3–4–6	96	95 76			8.6	1900 ?	
40	Nickel.	Ni	2–4	58 7	58 55	Nickelous salts	0 305009	8 8	1400	
41	Neodymium [2]. . .	Nd	3	143 6	143 15					
42	Neon	Ne	?	20						
	Niobium[3]	Nb or Cb	3–5	93 73	93 45					
43	Nitrogen.	N	1–3–5	14 03	14					
44	Osmium.	Os	2–3–4–6–7	191	190 7					
45	Oxygen.	O	2	16	15 96	Oxids	0.082872			
46	Palladium	Pd	2–4	106 6	106 33			11 8		
47	Phosphorus.	P	3–5	31	30 92			1 77		
48	Platinum.	Pt	2–4	195	194 51	Haloid salts	0.504560	21 5		
49	Potassium.	K	1	39 15	39	Haloid salts	0.405409	0 865	62	730
50	Praseodymium. . .	Pr	3	140 5	140					
51	Rhodium.	Rh	3	103	102 74					
52	Rubidium.	Rb	1	85.5	85 28					

[1] Glucinium = Berylium. [2] Neodymium and Praseodymium split from Didymium. [3] Niobium = Columbium.

ATOMIC WEIGHTS—(*Continued*).

	Substance	Symbol	Valency	Atomic Weights Oxygen = 16	Atomic Weights Hydrogen = 1	Electrolyte	Electro-chemical Equivalent Deposited by One Coulomb	Specific Gravity	Melting-point, Degree C.	Boiling-point, Degree C.
							milligrams			
53	Ruthenium.	Ru	2-3-4	101.68	101 35					
54	Samarium.	Sm	3	150.26	149 62					
55	Scandium.	Sc	3	44.12	43.89					
56	Selenium.	Se	2-4-6	79.02	78 80			4.788	212	1420
57	Silicon.	Si	4	28.40	28 33					
58	Silver.	Ag	1	107.93	107 65	Salts	1.118129	10.5	954	
59	Sodium.	Na	1	23 04	23	Haloids	0.238857	0 974	95.6	900
60	Strontium.	Sr	2	87.61	87 38	Haloids	0.453309	2 5	1100	
61	Sulphur.	S	2-4-6	32 06	31 98	Sulphids	0.166070	2 03	114.5	440
62	Tantalum.	Ta	5	182 8	182 13					
63	Tellurium.	Te	2-4-6	125	124 69			6.11		
64	Terbium.	Tb	5	160	159 6					
65	Thallium.	Tl	1-3	204.18	203 67			11.8		
66	Thorium.	Th	4-2	232 63	232					
67	Thulium.	Tu	1	170.7	170 27					
68	Tin.	Sn	4-2	119.05	118.70	Stannous salts Stannic salts	0.611699 0.305849	7.3	228	1550
69	Titanium.	Ti	4	48.15	47 88					
70	Tungsten.	W	2-4-6	184	183 54	Oxids Tungstates	0.635352 0.317676	18		
71	Uranium.	U	4-6	239.6	238 9			18.6		
72	Vanadium.	V	5-1-3	51.4	51.26					
73	Xenon.	Xe	?	128						
74	Ytterbium.	Yb	3	173.2	172 57					
75	Yttrium.	Y	3	89.1	88.88					
76	Zinc.	Zn	2	65.4	65.14	Salts	0.338635	7.1	415	940
77	Zirconium.	Zr	4	90.4	90.38					

Supposed elements not included: Radium, holmium, polonium, actinium, victorium, lucium, russium, disprosium, and europium.

Explanation: The symbols in chemical formulas and in chemical equations designate not only the substance but also the weight of the substance entering into the compounds represented by the formulas. This weight is the atomic weight. The numbers in the columns of hydrogen = 1 have been generally employed; but recently it has been proposed to use the numbers in the column oxygen = 16, in which case, from the most recent determinations, the atomic weight of hydrogen = 1.00275. However, according to tables published by E. W. Morley in 1895, for O = 16, H = 1 0076.

A small number at the right-hand lower or upper part of a symbol means that the atomic weight of the substance should be multiplied by that number. For instance, Al_2O_3 means $2 \times 27 = 54$ parts of aluminium are combined with $3 \times 16 = 48$ parts of oxygen to form alumina.

17. Weights in Vacuum.

Coefficients.

For reducing the weight of substances of various specific gravities, weighed in air with brass weights, to their equivalent weight in vacuum.

G, specific gravity; *C*, coefficient.

G	0.8	1.0	1.2	1.4	1.6	1.8	2	3	4	5	6
C	1.36	1.06	0.86	0.71	0.61	0.52	0.46	0 26	0 16	0.10	0.06
G	7	8	8.5	9	10	11	12	14	16	18	20
C	0.03	0.01	0.00	−0.01	−0.02	−0.035	−0.05	−0.06	−0.07	−0.08	−0.09

C, the coefficient found in the table, is to be multiplied with the weight in grammes; the product gives the number of milligrammes to be added to or to be deducted from the weight in air of the substance.

18. Table of Assay Tons.

In Grammes, Troy Ounces, and Troy Grains.

An assay ton contains as many milligrammes as there are Troy ounces in a ton of 2000 pounds adp.

Assay Tons	Gms.	Troy Grains	Troy Ounces	Assay Tons	Gms.	Troy Grains	Troy Ounces
1	29 1667	450 1102	0.9377	1.5	43.7500	675 1653	1.4065
2	58.3333	900 2204	1.8754	2 5	72 9167	1125.2755	2 3442
3	87 500	1350.3306	2.8131	3 5	102 0833	1575 3857	3.3819
4	116 6667	1800 4408	3.7508	4 5	131 2500	2025.4959	4 2196
5	145 8333	2250 551	4.6885	5 5	160 4166	2475 6061	5 1573
6	175 000	2700 6612	5 6262	6 5	189.5833	2925 7163	6 0950
7	204 1667	3150.7714	6.5609	7.5	218.7500	3375.8265	7.0327
8	233 3333	3600 8816	7.5016	8 5	247.8167	3825 9367	7 9704
9	262 500	4050 9918	8.4393	9 5	277 0833	4276 0469	8 9081
10	291 6667	4501 102	9 3771	10 5	306 2500	4726.1571	9.8459

19. ANALYTICAL COLOR INDICATORS.

Litmus Solution, Litmus-paper. Digest in 6 parts water, 1 part litmus; filter. To one half of the solution add nitric acid until color turns reddish; mix with the second half; add 1 part alcohol.

Normally blue, turns red by a drop of very weak acid solution, which a trace of base restores to blue. Reliable with alkaline sulphates, nitrates, chlorids, sodium sulphid, sodium silicate, and free oxalic acid.

Neutral with sodium thiosulphate and potassium nitrite.

Cochineal Solution, Cochineal Paper. Digest in 15 c.c. alcohol and 100 c.c. water, 1.5 grammes pulverized cochineal, stir, and after a few days filter.

Normally orange in an acid solution, turns purplish red by the addition of a saturating drop of weak solution of a base; by an added drop of acid, solution returns to ruby red, changing gradually to orange.

Methyl Orange. Dissolve 1 grm. in 1 litre of water. To 100 c.c of solution to be titrated are added 4 or 5 drops of the methyl-orange solution.

Pale lemon-yellow in alkaline solutions changes to pink by the addition of mineral acids.

Reliable with alkaline phosphates, sodium silicate, soda in

borax. Neutral with sodium thiosulphate. Inadmissible with potassium nitrite, free oxalic, acetic, tartaric, citric, carbonic acids, and lime-juice.

Phenolphthaleine, $C_{20}H_{14}O_4$: One gramme of the yellowish-white crystalline powder is dissolved in 100 c.c. of 50-per cent alcohol.

Normally colorless, remains colorlses in acid solutions By the addition of a solution of a base, a point is reached when the mixture turns suddenly red.

Reliable with potassic and sodic sulphates, nitrates and chlorids; sodium aluminate, free oxalic, acetic, tartaric, citric acids, and lime-juice.

Neutral with sodium thiosulphate, potassium nitrite.

Inadmissible with ammonia, ammonia salts, and soda in borax.

Phenacetoline. Boil for several hours phenol, acetic anhydride, and sulphuric acid in molecular proportions, wash with water, and dry. Dissolve 2 parts in 1000 parts 50-per cent alcohol.

Normally faint yellow when in excess with alkaline solutions; of a dark-pink color when saturated with acid. Reliable with alkaline sulphates, nitrates, phosphates, chlorids, and sodium aluminate. Neutral with sodium thiosulphate and potassium nitrites. Inadmissible with free oxalic, acetic, tartaric, citric acids, and lime-juice.

Congo Red. Dissolve 1 grm. in 100 grms. of 30-per cent alcohol. Add 10 drops to the liquid to be titrated.

Normally red, remains unaltered in neutral and basic solutions of salts. Free-acid solutions color it blue. Neutral with acid salts and organic acids. Inadmissible with alkaline sulphates, sulphites, nitrates, and chlorids.

20. REAGENTS.

Wet analysis (Wt.), dry assay (Dy.), and blowpipe analysis (Bl.).

Carbonate of Soda, $Na_2CO_3 10(H_2O)$. Loses $10(H_2O)$ at 100° C., is used in Wt, Dy, Bl.

Bicarbonate of Soda, $NaHCO_3$, Wt, Dy, Bl The sulphur in both can be detected by mixing 2 parts of sodium carbonate with 1 part of borax and fusing the mixture on char-

coal in the reducing-flame of a blowpipe. The powdered mass when cool is moistened on a bright surface of silver foil or of a silver coin. A black spot is produced when sulphur is present.

Carbonate of Potash, K_2CO_3, Wt., Dy. Being very deliquescent, it should be kept powdered in a glass-stoppered bottle for dry assay.

Potassic Nitrate, Saltpetre, Nitre, KNO_3, Wt., Dy. Should be kept dry in a finely powdered state. It is used as a flux and as oxidizing agent in dry assay.

Borate of Soda, Borax, $Na_2O2(Bo_2O_3)+10(H_2O)$, Dy., Bl. The commercial article is purified by crystallization. Calcine and vitrify the dried crystal, and preserve as a coarse powder.

Boracic acid, $Bo_2O_3+3(H_2O)$, Dy. Loses $2(H_2O)$ at 100° C., and the remaining H_2O at a red heat.

Bitartrate of Potash, Cream of Tartar, Hydropotassic Tartrate, Argol (crude), $C_4H_4O_5KHO$, Dy **Black Flux** is the residual after calcination, and is an intimate mixture of carbon and carbonate of potash; it is to be kept in a powdered state and dry.

Black Flux Substitute, Dy.: Mix 10 parts bicarbonate of soda with 3 parts of flour and calcine.

Wood Charcoal, C., Dy.: Is used powdered as a reducing and as a desulphurizing agent.

Salt of Phosphorus, Double Phosphate of Soda and Ammonia, Microcosmic Salt, $NaNH_3PO_3H_2O$, Bl. Dissolve in 100 parts of hot distilled water, 32 parts phosphate of soda, and 16 parts salammoniac. Filter hot, dry the crystals which form on cooling, and keep as coarse powder. The glass formed in the blowpipe flame should be transparent and remain so on cooling.

Nitrate of Cobalt, $N_2CoO_42(H_2O)$, Bl. Dissolve protoxid of cobalt in dilute nitric acid, evaporate. The red crystals so obtained dissolve in 10 parts of distilled water and keep in ground-glass stoppered bottles.

Oxalate of Cobalt, CoO, $C_4H_4O_8$, Bl. Used as a powder, as a substitute for nitrate.

Carbonate of Ammonia, $4(NH_3)3(CO_2)+2H_2O$, Wt., Dy. Used in the shape of a fine powder for desulphurizing roasting ore.

Potassic Cyanid; Cyanid of Potassium, $KNC = KCy$, Wt., Dy. Used granulated or pulverized, should be kept dry. Desulphurizing and reducing agent Is very poisonous.

Ferrocyanid of Potassium; Yellow Prussiate of Potash, $FeK_4Cy_6 + H_2O$, Wt. Keep in solution 1 part in 12 parts distilled water.

Bichromate of Potash; Potassic Dichromate, $K_2Cr_2O_7$, Wt. Dissolved in distilled water for determination of carbon in iron

Iodid of Potassium, KI, Wt Employed solid or as a dissolution of 1 part in 10 parts of distilled water

Sulphocyanid of Potassium, KSKCy, Wt. Dissolution of 1 part in 10 parts of distilled water.

Permanganate of Potash, $KMnO_4$, Wt Dissolve 0 3952 gramme in 1 litre of distilled water. One centimetre cube of this solution contains 0 1 milligramme of available oxygen

Caustic Potash; Potassic Hydrate, KHO, Wt Solution of 1 part in 10 parts distilled water, for iron and steel 300 grms. in 1 litre of water for CO_2.

Hyposulphite of Soda; Sodium Thiosulphate, $Na_2S_2O_3 + 5(H_2O)$, Wt Melts at 56° C., loses its crystallization water at 100° C Decinormal solution consists of 24 8 grms. in 1 litre of distilled water.

Sulphate of Iron; Green Vitriol; Copperas, $FeSO_4 + 7(H_2O)$, Wt. Use dissolved in distilled water. At 100° C. it loses $\frac{6}{7}$ of its crystallization water.

Chlorid of Barium; Muriate of Baryta, $BaCl_2 + 2(H_2O)$, Wt. Dissolve 1 part in 10 parts of distilled water. If 10 c c of this solution are poured in a solution of a sulphate salt, 1 16 grammes of barium sulphate, $BaSO_4$, are precipitated, containing 0.4 grm. of sulphuric acid, SO_3, or 0.16 grm. sulphur, S.

Mercuric Chlorid: Corrosive Sublimate, $HgCl_2$, Wt Dissolve **1 part in 10 parts of distilled water;** dilute as required.

Stannous Chlorid; Protochlorid of Tin, $SnCl_2 + 2(H_2O)$, Wt. Dissolved in distilled water it reduces peroxids to protoxids and sometimes to the metallic state when they are combined with acids.

Citrate of Ammonia, $N_2H_{16}C_{12}O_{12}$, Wt : To be dissolved in distilled water.

Chlorid of Sodium; Common Salt, NaCl, Wt.: For silver determination dissolve 5.417 grammes, chemically pure, in

litre of distilled water (Gay-Lussac). One cubic centimetre of this solution will precipitate one centigramme of silver from its solutions.

From a solution of 58.5 grammes of sodium chlorid, chemically pure, in 1 litre of distilled water, 1 c.c. will precipitate from a silver solution 108 milligrammes of silver, called one milligramme equivalent of silver

Nitrate of Silver, $NAgO_3$, Wt.: From a solution of 4.8022 grms ch. p in 1 litre of distilled water, 1 c c precipitates silver chlorid, from a sodic-chlorid solution, containing 1 milligramme of chlorin

Peroxid of Manganese; Manganese Dioxid; Black Oxid of Manganese, MnO_2: One litre of chlorin gas will be produced at 0° C. and 0 760 barometric pressure by 3.98 grammes of pure peroxid and 25 to 30 c.c. of pure liquid hydrochloric acid.

Litharge; Yellow Oxid of Lead; Plumbic Monoxid, PbO, Dy.: Fuse, pour in a cold mold, pulverize, and keep in a well stoppered bottle from contact with air.

Silica; Silicic Acid; Silicic Dioxid, SiO_2, Dy: Precipitated silica to be used as a flux.

Sulphuric Acid; SH_2O_4, Wt., Bl.: At maximum concentration the acid boils at 325° C. = 617° F. It congeals at −35° C = −31° F. At a temperature of 15° C. = 59° F. its density is 66° Baumé, or 1.848 specific gravity.

Normal solution 60 grms. in 1050 c.c. of distilled water.

Hydrochloric Acid; Muriatic Acid: As a gas ClH, liquid or dissolved in water $ClH+3(H_2O)$, Wt., Bl.: Gaseous at ordinary temperature and pressure. The saturated solution in water contains 0 75 acid for 1 part of water by weight. Specific gravity of the solution, 1.21.

Nitric Acid, NHO_3, Wt , Bl.: The specific gravity at maximum concentration is 1.51, boiling-point 86° C. = 186.8° F., congelation-point −55° C. = −67° F.

A hydrated acid of the formula $N_2O_5 4(H_2O)$ boils at 123° C. = 252.4° F

Aqua-regia, Wt., Bl.: This is a mixture of concentrated nitric and hydrochloric acids in various proportions.

The mixture in proportion to atomic weights consists of 7 parts nitric acid to 10 parts by weight of hydrochloric acid.

A mixture often employed is 1 part nitric and 4 parts hydrochloric acid.

A test acid for gold on touchstones consists of a mixture of nitric acid, sp. gr. 1.34, 98 parts, and hydrochloric acid, sp. gr. 1.173, 2 parts.

Molybdic Acid, Wt Various molybdate solutions

1 In 417 c c. of ammonia sp gr 0 96 dissolve 100 grms molybdic acid. Pour this solution slowly in 1250 c c of nitric acid sp gr. exactly 1.20 Keep in a warm place for several days, decant from sediment and preserve for use

2 In a mixture of 62 c c distilled water and 333 c c ammonia of 0 95 sp. gr dissolve 123 grms of crystallized molybdate of ammonia, and under stirring add 1250 c c nitric acid of 1.2 sp. gr. After several days syphon the clear liquid off for use.

Magnesium Chlorid, $MgCl_2+6H_2O$, Wt : For the preparation of the magnesia mixture, dissolve 110 grms of crystallized magnesium chlorid in distilled water, or dissolve magnesia, MgO, recently ignited in dilute hydrochloric acid When dissolved add magnesia, MgO, slightly in excess; boil, filter, then add 28 grms. ammonium chlorid dissolved in 700 c.c of ammonia, sp. gr. 0.96, and finally dilute with distilled water to 2 litres.

Cuprous Chlorid, CuCl, Wt.: Of scant solubility in water, it is used as an absorbent of carbon monoxid, CO.

Pyrogallic Acid, $C_6H_6O_3$, Wt : Is used as an absorbent of free oxygen.

21. NORMAL SOLUTIONS

In Distilled Water for Volumetric Analysis.

1 c.c. of any acid neutralizes 1 c.c. of any alkali solution.

Number of Grms. of Acids in 100 c.c. of Normal Solution		Number of Grms. of Alkalies in 100 c.c of Normal Solution	
H_2SO_4, Sulphuric. . . .	4 900	NH_3, Anhydrous ammonia	1.700
HNO_3, Nitric. . . .	6 300	NH_4OH, Ammonia hydrate.	3.500
HCl, Hydrochloric. .	3 640	$NH_4HCO_3.NH_4NH_2CO_2$	5 233
HI, Hydriodic. . . .	12 760	KOH, Potassium hydrate.	5 600
HBr, Hydrobromic. .	8.080	K_2CO_3, Potassium carbonate. . . .	6 900
$HCHO_2$, Formic.	4 600	$KHCO_3$, Potassium carbonate . .	10 000
$HC_2H_3O_2$, Acetic .	6 000	NaOH, Sodium hydrate. . . .	4 000
$H_2C_2O_4+2H_2O$, Oxalic	6 300	Na_2CO_3, Sodium carbonate . .	5 300
$H_2C_4H_4O_6$, Tartaric.	7.500	$Na_2CO_3+10H_2O$, Sodium carbonate	14 300
$H_3C_6H_5O_7+H_2O$, Citric	7.000	Na_2HCO_3, Sodium carbonate. . . .	8 400
$HC_3H_5O_3$, Lactic. . .	9 000	$Ca(OH)_2$, Calcium hydrate	3 700
$HC_7H_5O_3$, Salicylic. . .	13.800	$CaCO_3$, Calcium carbonate.	5 000
$HC_7H_5O_2$, Benzoic . . .	12.200	$Ba(OH)_2$, Barium bydrate.	8.534

22. PRELIMINARY HEAT TESTS OF MINERALS.

For ascertaining the presence of the hereafter indicated substances in a mineral compound, by means of an ordinary or of a blowpipe flame.

R = reducing, O = oxidizing flame.

Ammonia: Mix any ammonia salt with carbonate of soda; heat in a glass tube closed at one end. A sublimate of carbonate of ammonia will be formed in the cold part of the glass tube; the ammonia vapor may be recognized by the odor, or by the formation of white vapor around a glass rod dipped in dilute hydrochloric acid, held over the mouth of the glass tube

Nitric Acid: Nitrates deflagrate when heated on charcoal Heated in a glass tube closed at one end they emit red fumes of nitrous acid. If in small proportions mix the nitrate with bisulphate of potash before heating in the tube.

Sulphur and Sulphuric Acid: Sulphids heated in the O-flame emit sulphurous vapors of the well-known odor. Heated in the closed end of a glass tube, a yellow sublimate of sulphur forms in the cold part of the tube.

The powdered substance mixed with two parts soda and one part borax heated on charcoal in the R-flame, forms a mass, a little of which moistened on a bright silver surface of a coin produces a black spot if sulphur or sulphuric acid was present in the mineral.

Chlorin: In salt of phosphorus on a platinum wire dissolve oxid of copper in the O-flame, add powdered mineral, expose to flame If the assay is enveloped by a blue or purple flame, then chlorin is present.

If the mineral is soluble, add a drop of the solution to a few drops of copper or iron sulphate solution on a bright silver surface A black spot on the silver indicates the presence of chlorin in the mineral.

Bromin: With the same treatment indicated for chlorin, bromin will impart to the flame a greenish coloration.

Iodin: Free iodin imparts to a solution of starch-paste a blue color.

Fluorin: To the pulverized mineral in a glass tube add sufficient sulphuric acid to moisten it and submit to a gentle heat.

when hydrofluoric acid will be evolved, which will corrode the glass of the tube.

Phosphoric Acid: A small piece of the mineral held in platinum tongs and dipped in sulphuric acid when heated at the point of the blue flame will impart to the outer flame a greenish-blue color.

23. BLOWPIPE ANALYSIS.

APPARATUS.

1. One blowpipe. 2. One oil-lamp, candle, or gas-burner. 3. One piece of charcoal of light wood, having plane, smooth surfaces. 4. Several pieces of horse-hair platinum wires with loops. 5. One platinum foil. 6. One aluminum foil $1\frac{1}{2}'' \times 5''$. 7. A number of hard glass tubes free of lead, 5″ to 8″ long, $\frac{1}{4}$ to $\frac{5}{16}$ inch bore, some closed at one end, others open at both ends. 8. One pair of forceps with platinum points. 9. One mortar with pestle, both of agate or of hard-burned clay, small size. 10. One hammer of steel, hardened and polished. 11. One anvil of steel, hardened and polished, small size. 12. One magnet. 13. One magnifying glass. 14. An assortment of small watch-glasses. 15. One three-cornered saw-file.

23a. TABLES OF PHYSICAL AND CHEMICAL CHARACTERISTICS.

Preliminary Remarks on the Construction and Use of the Characteristic and Mineralogical Tables.

The following tables have been compiled for the purpose of enabling any amateur, capable of determining specific gravities and familiar with the use of the blowpipe, to determine approximately the constituent parts of any mineral which may come under his observation.

The crystallographic part, which in itself forms a science, is indicated only by the crystalline system to which any particular crystal may belong.

The classification in the Tables of Mineral Characteristics has been established approximately in accordance with the order of importance or usefulness of the metal or metalloid

which forms the principal or predominant constituent of the mineral.

The reference numbers in the first column of the Table of Mineral Characteristics are repeated on the second page of the Tables, this second page being a continuation of the first page. The same reference numbers with the chemical symbols of the classified metal or metalloid will be found opposite the names in the **"Alphabetical List of Minerals."**

The headings of the different columns in the **"Tables of Mineral Characteristics"** correspond with the titles of the different **Tables of Physical and Chemical Characteristics,** comprising the Tables of Physical Properties from 24a to 24f and the tables indicating chemical tests from 25 to 28. Each table contains, opposite reference numbers or reference letters, words, or sentences, designating any specific physical or chemical characteristic of minerals, which have been examined and subjected to treatment with the various chemical agents indicated. The same reference numbers or reference letters in the various columns of the tables of **"Mineral characteristics"** should therefore be translated in the words or sentences which they represent.

A mineral sample may consist of a mixture of several mineralogical specimens, in which case the different parts should be separated mechanically and each specimen should be examined and treated separately The observed physical and chemical characteristics of the mineral specimen under examination should be recorded on a sheet of blank paper, lined into columns similar to the columns of the Tables of **"Mineral Characteristics,"** and provided with the same headings and in the same order The recording should be done by means of the reference numbers or letters corresponding with the statements of similar or closely analogous characteristics in the explanatory tables The resulting record being then compared with that contained in the Tables of **"Mineral Characteristics,"** will at once show the class and probably indicate the particular name of the mineral examined, if the latter belongs to the more common, but at the same time more important kinds of minerals. For rarer minerals and for minerals requiring a minute distinction of their crystalline forms, reference should be had to some good treatise on mineralogy.

24. TABLES OF PHYSICAL PROPERTIES OF MINERALS.

Note: All reference numbers or letters in the following tables are used in the Tables "**Mineral Characteristics**," in the columns headed by the title of each of the explanatory tables as representatives of the qualifying word or sentence following the reference number or letter:

24a. Condition and Structure.

a	Malleable	1	Massive	8	Fibrous separable	15	Globular
b	Ductile	2	Amorphous	9	Radiated	16	Reniform
c	Sectile	3	Lamellar	10	Earthy	17	Stalactitic
d	Flexible	4	Foliated	11	Stellate	18	Granular
e	Elastic	5	Micaceous	12	Concentric	19	Acicular
f	Brittle	6	Columnar	13	Mamillary	20	Filiform
g	Tough	7	Fibrous compact	14	Botryoidal	21	Crystalline
l	Liquid						

24b. Hardness.

1 is the softest and 10 is the hardest mineral.
(A sharp edge or corner of a mineral with a higher number will scratch the minerals of the lower numbers.)

1	Talc, Kaolin, Graphite	6	Orthoclase, Opal
2	Gypsum, Sulphur, Brucite	7	Quartz, Tourmaline
3	Calcite	8	Topaz, Spinel
4	Fluorite	9	Corundum, Ruby
5	Apatite	10	Diamond

24c. Specific Gravity.

Solids and Liquids. Call the specific gravity of a substance heavier than water G.

Its weight in air $=W$. Its weight in water $=w$. Then the weight of the same volume of water as the substance examined is $W-w$ and the specific gravity is

$$G=\frac{W}{W-w}.$$

Substance lighter than water, call its specific gravity g.

Its weight in air $=W_1$. The weight in water of a substance heavier than water $=w$. The weight in water of the light and

heavy substances attached together $=w_2$. Then the weight in water of the lighter substance $=w_2-w$, and

$$g=\frac{W_1}{W_1-(w_2-w)}=\frac{W_1}{W_1+w-w_2}.$$

Liquids.—Weight in water of a solid substance heavier than water $=w$. Weight of the same substance in the liquid to be examined $=w_{11}$. Weight of the solid in air $=W$. Weight of water displaced by the solid $=W-w$. Weight of liquid displaced by the same solid $=W-w_{11}$.

Then the specific gravity of the liquid

$$G_1=\frac{W-w_{11}}{W-w}.$$

24d. Crystalline Systems.

Normal Crystal Forms and their Limiting Surfaces.

I. Isometric, Monometric or Tesseral System.

Three axes of equal length perpendicular to each other. Three equal perpendicular planes of symmetry. Six equal diagonal planes of symmetry.

Cube: 6 equal squares.

Octahedron: 8 equal equilateral triangles.

Dodecahedron: 12 equal rhombs

Tetrahexahedron: On each of the squares of a cube is a pyramid of 4 equal isoscele triangles, in all 24 equal isoscele triangles

Trigonal-trisoctahedron: On each of the 8 equilateral triangles of the octahedron is a triangular pyramid formed by 3 equal isoscele triangles in all 24 equal isoscele triangles.

Tetragonal-trisoctahedron, or Trapezohedron: Each of the 8 equilateral triangles of the octahedron is replaced by 3 equal trapeziums, in all 24 equal trapeziums.

Hexoctahedron: Each of the 8 equilateral triangles of the octahedron is replaced by 6 equal scalene triangles, in all 48 equal scalene triangles

Tetrahedron: 4 equal equilateral triangles.

Pyritohedron: 12 irregular pentagons.

II. Tetragonal or Dimetric System.

Three axes perpendicular to each other, two of which are of equal length, the third being longer or shorter. One pair of equal planes of symmetry normal to the faces, one pair of equal planes of symmetry diagonal, and one plane perpendicular to the two.

Square prism: 2 equal opposite squares and 4 equal adjacent rectangles.

Double square pyramid: 8 equal isoscele triangles limiting 2 equal pyramids with a common square base.

Sphenoid: 4 equal isoscele triangles

Octagonal prism: 2 octagonal bases the opposite sides being equal and part of the sides of a square; the adjacent sides unequal; 8 rectangles with equal opposite planes and unequal adjacent planes.

Octagonal double pyramid, or Zirconoid: 16 isoscele triangular surfaces, alternate surfaces around the octagonal base being equal, adjacent surfaces unequal, the opposite equal sides of the base being parts of the sides of a square.

III. Hexagonal System.

Three axes of equal length in the same plane inclined 60° to each other, and one axis of more or less length, perpendicular through the point of intersection of the three axes.

Three equal planes of symmetry normal and three equal planes of symmetry diagonal to the faces, intersecting in the vertical axis and one plane of symmetry perpendicular to this axis

Hexagonal prism: 2 equal regular hexagonal bases perpendicular to the vertical axis. 6 equal rectangles parallel to the vertical axis.

Hexagonal double pyramid: 12 equal isoscele triangles constituting two pyramids with a common regular hexagonal base.

Twelve-sided prism: 2 12-sided bases, 6 alternate sides of which belong to the regular hexagon, the other 6 sides being diagonal to the first. 12 rectangles perpendicular to the bases, opposite faces being equal, while adjacent faces may or ma-not be equal.

Twelve-sided double pyramid: 12 isoscele triangles forming two equal pyramids with a common base of 12 sides, 6 alternate

sides of which belong to a regular hexagon, the other 6 being diagonal to the first Opposite faces of each pyramid are equal, while adjacent faces may or may not be equal.

IV. Rhombohedral System.

This having the same axes and planes of symmetry as the hexagonal is only distinguished from the latter by the difference of form.

Rhombohedron: 6 equal rhombs.

Scalenohedron: 12 equal scalene triangles forming a solid somewhat similar to a hexagonal double pyramid, with the edges formed by the base-line zigzag instead of straight.

V. Orthorhombic or Trimetric System.

Three unequal axes at right angles to each other. Three planes of symmetry each different from the other.

Rectangular prism: 6 rectangles of which two opposite faces only are equal.

Rhombic prism: 2 equal rhombic bases and 4 equal rectangles

Rhombic double pyramid: 8 equal scalene triangles forming two equal pyramids with a rhomb for common base. The angles formed by similar edges in all the triangles are the same

VI. Monoclinic, Monoclinate System.

Three unequal axes, two of which are at right angles to each other, the third being oblique to the plane of the first two.

One plane of symmetry.

Right rhomboidal prism: Two equal parallelogram or rhomboid bases and 4 rectangular surfaces, the two opposite faces being equal and parallel.

Oblique rhombic prism: 2 equal and parallel rhombic bases and 4 symmetrical rhomboids or parallelograms.

VII. Triclinic or Triclinate System.

Three unequal axes all oblique to each other. No plane of symmetry. Like surfaces are in pairs only on opposite sides of the crystal.

Oblique rhomboidal prism: 6 rhomboids. Two opposite faces being equal and two adjacent faces unequal.

24e. Color and Lustre.

Ref. No.	Color	Ref. No	Color	Ref No.	Lustre
0	Variety of colors	13	Light blue	*a*	Metallic
1	Colorless	14	Blue	*b*	Adamantine, Brilliant
2	White	15	Dark blue		
3	Light gray	16	Light brown	*c*	Vitreous
4	Gray	17	Brown	*d*	Resinous
5	Dark gray	18	Dark brown	*e*	Pearly
6	Black	19	Light green	*f*	Silky
7	Light yellow	20	Green	*g*	Opalescent
8	Yellow	21	Dark green	*h*	Iridescent
9	Dark yellow	22	Light violet	*i*	Velvety
10	Light red	23	Violet	*j*	Dull
11	Red	24	Dark violet	*k*	Earthy
12	Dark red	25	Various Colors on the same mineral	*l*	Banded
				m	Spotted

In the tables "30. **Mineral Characteristics**," colors are indicated by the reference numbers in the above table 24*e*, and lustres by the reference letters thereof The different colors of a number of specimens of the same mineral are indicated by 0, a variety of colors. Colorless, 1, is a substance assumed to be, when it is supposed that an object, with its unmodified colors, may be visible through two parallel polished plane surfaces of the substance.

Numbers separated by commas, as 8, 11, 17, indicate distinct colors· yellow, red, brown; while shaded colors, as 7.11, yellowish-red, or 13.2, bluish-white are represented by numbers separated by a period, the shading color preceding the predominant one.

24f. Fracture. Optic, Magnetic, Electric Properties.

Taste, Odor, Solubility of Mineral in Water.

	Fracture and Solubility in Water		Taste Odor		Odor Optic, Electric, Magnetic
1	Crystalline	1	Cooling as saltpeter	13	Fetid odor
2	Cleavable	2	Saline as common salt	14	Aromatic odor
3	Coarsely granular	3	Astringent as alum	15	Osmic odor
4	Fine granular	4	Alkaline as soda	*a*	Transparent
5	Fibrous	5	Bitter as Epsom salt	*b*	Translucent
6	Conchoidal	6	Sour as acid	*c*	Opaque
7	Earthy	7	Sweet as sugar	*n*	Double refractory
8	Waxy	8	Sulphurous odor	*d*	Electric by friction
A	Deliquescent	9	Argillaceous odor	*e*	Electric by heat
B	Very soluble	10	Alliaceous odor	*f*	Magnetic naturally
C	Soluble	11	Horse-radish odor	*g*	Magnetic after roasting
D	Slightly soluble	12	Bituminous odor		

25. Acid Tests.

Reduce the mineral to the size of fine grains. Try a few grains in a little strong acid in a small test-tube. If a strong effervescence takes place, dilute the acid with water If no action is apparent, heat the acid gently and note the results.

Explanation: $h\ s\ n$ represent dilute and $h_1\ s_1\ n_1$ represent concentrated hydrochloric acid (h), sulphuric acid (s), and nitric acid (n), all at ordinary temperature or cold. $\cdot h\ \cdot s\ \cdot n$ represent the same acids heated $h'\ s'\ n'$ to $h^8\ s^8\ n^8$ indicate the emission of gas by dissolution in the acids. $(hs)\ (hn)\ (sn)$ represent mixtures of the respective acids

Example: The action on a substance, easily soluble in cold dilute hydrochloric acid with emission of hydrogen, not soluble in sulphuric acid and only soluble in hot concentrated nitric acid emitting nitrous acid gas, will be represented by $h'\ s_0\ \cdot n_1^6$. The action on a substance, insoluble in any of the acids singly or in any other media indicated, but soluble in hot aqua regia, emitting chlorin, would be represented by $0\ \cdot(hn)^4$.

0	Insoluble in any of the acids or media indicated, cold or hot.	
1	Soluble in pure water.	
2	Soluble in alcohol	
3	Soluble in sulphuric ether, all cold.	
$h_0\ s_0\ n_0$	No or very little action by any of the three acids singly, cold or hot.	
$h\ s\ n$	Dissolves in cold dilute acid.	No emission of gas.
$\cdot h\ \cdot s\ \cdot n$	Dissolves in hot dilute acid.	
$h_1\ s_1\ n_1$	Dissolves in cold concentrated acid.	
$\cdot h_1\ s_1\ \cdot n_1$	Dissolves in hot concentrated acid.	
$(hs)(hn)(sn)$	Dissolves in a mixture of acids.	
$h'\ s'\ n'$	Hydrogen, H.	Emitted by dissolution.
$h^2\ s^2\ n^2$	Carbonic acid, CO_2.	
$h^3\ s^3\ n^3$	Sulphuretted hydrogen, HS.	
$h^4\ s^4\ n^4$	Chlorin gas, Cl.	
$h^5\ s^5\ n^5$	Nitrogen perovid, NO.	
$h^6\ s^6\ n^6$	Nitrous acid, NO_2	
$h^7\ s^7\ n^7$	Sulphurous acid SO_2.	
$h^8\ s^8\ n^8$	Hydrofluoric acid, HF.	
$h_2\ s_2\ n_2$	**Solutions gelatinize on cooling.**	

$h_3 s_3 n_3$ Solutions precipitate metals on the introduction of other clean metal therein, as clean iron dipped in a copper solution is covered with copper; clean copper dipped in a silver solution will be silvered.

$h_4 s_4 n_4$ Introduced into a solution produces a precipitate therein.

Identification of gases.—Hydrogen burns in air and explodes mixed with air. Carbonic acid extinguishes a burning match. Chlorin is greenish-yellow in color and has a suffocating smell. Sulphuretted hydrogen smells similar to rotten eggs. Nitrogen peroxid revives a faint ember on a match. Nitrous acid emits reddish vapors. Sulphurous acid has the odor of burning sulphur. Hydrofluoric acid corrodes glass.

26. Heat Tests.

Candle, lamp, or gas flame, G.; blowpipe flame, B.; O., oxidizing flame; R., reducing flame.

0. Burns when heated with a more or less colored flame.
1. Fuses easily in G.
2. Melts in large fragments in G.
3. Melts in fine particles in G. or in fragments in B.
4. Melts from small splinters to globules in B.
5. Thin edges rounded in B.
6. Very difficult to fuse in B.
7. Infusible in B.
8. Swells and fuses into globules in G. and B.
9. Intumesces and fuses or becomes pulverulent in G. or B.
10. Exfoliates by the application of heat or effloresces on exposure.
11. Decrepitates.
12. Glows or phosphoresces in B. before fusing.
13. Fuses on charcoal to a globule in R., becoming magnetic.*
14. Fuses to a globule of suboxid, converted into metal with carbonate of soda on charcoal by the R.
15. Fuses on charcoal and is reduced to metal in R.
16. Fuses on charcoal and evaporates into fumes in B.

* Magnetic here means liable to be attracted by a magnet.

17. Applying a drop of sulphuric acid after heating to redness and reheating imparts to the flame a color.
18. Applying a drop of cobalt solution after heating to redness and reheating imparts to the mineral a color.
19. On charcoal in B. produces antimonial, arsenical or sulphurous fumes, distinguished by odor or sublimate.
20. Changes color and loses transparency in B
21. Fuses in B. on charcoal, the globule obtained, becomes angular on cooling.
22. Fuses in B to a globule, scoriae or glass of different color.
23. Emits sulphurous fumes before B., boiling in O., and changes to metallic globule
24. Changes color in B. or loses transparency without melting.
25. Fuses in B to a scoriae on charcoal with soda, mixed with more soda and fused again, deposits a sublimate.
26. Changes color in B, but loses the color on cooling.
27 Fusible with sulphur
28. Reduced to metal in R on charcoal with soda.
29 Produces a strong flame on charcoal in B.
30 Melts with soda on charcoal in B
31. Froths in B and melts to a slag or mass on charcoal.

27. Heat Tests in Glass Tubes.

Glass tubes 5″ to 8″ long ¼″ to $\frac{5}{16}$″ bore.

Put a small fragment of the mineral (about the size of a mustard seed) in the tube and heat slowly in a candle or gas flame

Glass Tube Closed at One End.

1 Melts, evaporates, and condenses wholly in cold part of the tube
2 Melts, evaporates partially, part remaining solid at bottom, part condenses in cold part of tube.
3 Evaporates and is wholly condensed in cold part of tube, without change of composition.
4. Evaporates and is wholly condensed in cold part of tube, with change of composition.
5. Evaporates and condenses partially in cold part of tube, leaving a solid residue.

Glass Tube Open at Both Ends.

a. Evaporates completely and is discharged as a gaseous product of combustion.
b. Evaporates and is partially condensed in the cold part of tube, and partially discharged as a gaseous product of combustion.
c Evaporates partially with gaseous discharge leaving a solid residue.
d. Evaporates and is converted in a compound condensing in cold part of tube.

28. Pyro-chemical or Blowpipe Tests.

With Borax or Phosphorus Salt, and on Charcoal.

O, oxidizing flame; R, reducing flame

Manipulation: Dip the heated loop of a platinum wire in powdered borax or phosphorous salt, fuse, add until a clear bead fills the loop, then dip in the powdered mineral and expose to blowpipe flame.

The use of phosphorus salt is indicated by a point on the left of the reference number.

Under "Borax or Phosphate Beads," tables of "Mineral Characteristics," a number expresses color. A letter preceding the number indicates the behavior of the mineral expressed opposite reference letters from *a* to *j* as follows:

a In O the mineral forms an oxid soluble in borax, imparting to the borax bead a characteristic color, hot or cold.
b. In R the dissolved oxid is reduced in the borax bead to a suboxid of different color, hot or cold, or to metal.
c. In the O the mineral with salt of phosphorus forms an oxid of characteristic color, hot or cold.
d. In R. the oxid dissolved in the salt of phosphorus is reduced to an oxid of different composition also of characteristic colors, hot or cold.
e. On charcoal a sublimate is formed of characteristic color near assay.
The sublimate is of different color at a distance from assay.

28a. Borax Beads.

Heat the clean loop of the platinum wire to redness and dip in powdered borax; repeat as often as necessary to fill the loop. The bead so obtained should be clear and colorless, hot and cold. Dip the melted borax bead in the powdered mineral and fuse in the oxidizing flame until complete dissolution has taken place. Note the rapidity of dissolution, the evolution of gas, the appearance and color of the bead, hot and cold. If more mineral than necessary has been taken up, the bead may be opaque and should then be flattened or drawn out to a thread in order to observe the color. Beads, clear, hot, and cold, may become opaque, opalescent, or milk-white by being heated in an intermittent or in a reducing flame.

Beads on charcoal should be heated in a small cavity in the coal; when perfectly fused, press the bead flat with platina forceps.

Soluble in borax are the earth and all metallic oxids native, or derived from combinations with metalloids by roasting, or from salts by expulsion of the acids by heat. Easily reducible metals like platinum, gold, etc., and volatile metals like mercury form no oxids and are therefore not dissolved in borax.

28b. Beads of Microcosmic Salt,

or of

Phosphate of Soda and Ammonia.

By heat the ammonia is driven off and the flux becomes a biphosphate of soda. Almost all substances except silica dissolve in a bead of this flux. Sulphids and arsenites should be treated on charcoal. Earth and metallic oxids are best treated in a loop of platinum wire with an extra turn, as the microcosmic salt is more fluid than borax. The colors appear more distinctly, and may be obtained in either flame. If obtained in the reduction flame, the bead should be cooled as quickly as possible.

28c. Colors of Borax and Salt of Phosphorus Beads.

By treating various substances in the blowpipe flame.

O., oxidizing; R., reducing flame; H., hot; C., cold. For colors indicated by numbers, see Table 24c

Name of Substance	Numbers Indicating Colors							
	Borax Bead				Slt. Phosphorus Bead			
	O		R		O		R	
	H	C	H	C	H	C	H	C
Silica[1]	1	1	1	1	1	1	1	1
Alumina	1	1	1	1	1	1	1	1
Oxid of tin	1	1	1	1	1	1	1	1
Baryta	1	1	1	1	1	1	1	1
Strontia	1	1	1	1	1	1	1	1
Lime	1	1	1	1	1	1	1	1
Magnesia	1	1	1	1	1	1	1	1
Glucina	1	1	1	1	1	1	1	1
Yttria	1	1	1	1	1	1	1	1
Zirconia	1	1	1	1	1	1	1	1
Thoria	1	1	1	1 [2]	1	1	1	1 [2]
Oxid of Lanthanum	1	1	1	1	1	1	1	1
" " Cerium	7.11	2 [3]	1	2–1 [3]	10 9	1	1	1
" " Didymium	23	23	1	1	23	23		
" " Manganese	23	11–23	1	1	23	23		
" " Silver		b [3]	4 [5]	1	7		4 [5]	1
" " Zinc	7 [4]	2 [4]	4 [5]	4 [5]				
" " Cadmium	7 [4]	2 [3]	4 [5]	4 [5]	7 [2]	1		
" " Lead	8 [4]	1	4 [5]	4 [5]	8 [2]	2 [2]	3	
" " Bismuth	9 [4]	1	4 [5]	4 [5]	8	1		
" " Antimony	8 [4]	1	4 [5]	4 [5]	7	1		
" " Nickel	23	10.17	4 [5]	4 [5]	10	7		7.17
" " Iron	12	8	21	13.20	7.17	16.11	11	3.11
" " Chromium	8	7.20	20	20	7 11	20	20	20
" " Cobalt	14	14	14	14	14	13	14	13
" " Uranium	8 11	7	4.20	13 20	8	19.8	20	20
" " Copper	20	19 14	1	12	20		21 [2]	16 11
Tantalic acid	1	1	1	1	1	1	4	4
Telluric "	1	1	4	4	1	1	4	4
Titanic "	1	1	9	9	1	1	8	23
Tungstic "	8	1	8	8	8	1	14	14
Niobic "	1	1	1	1	1	1	14	14
Vanadic "	8	8	8	20	8	8	19	20
Molybdic "	8	1	8	8	7.20	7.19	20	20

[1] Slightly soluble in salt of phosphorus.
[2] Saturated.
[3] Intermittent flame.
[4] In large quantity; in small quantity lighter colored.
[5] After long-continued blowing.

28d. COLORS RESULTING BY TREATMENT OF METALLIC OXIDS IN FLAME.

B., blowpipe; O., oxidizing; R., reducing flame; Ch., charcoal.

Potassium.	In O. colors flame distinctly	Violet	23
	Trace of sodium or lithium salts obliterates color. Observed through a cobalt-blue glass, even if sodium is present, the color is	Red	11
Sodium.	In O., the flame is enlarged and intense	Reddish yellow	10.8
	Not obliterated by other substances, only more or less modified according to the quantity of sodium present		
Lithium.	In O. the flame is colored a fine	Red	11
	shown especially by chlorid of lithium. A small quantity of sodium changes the color to	Yellowish red	7.11
Barium.	In O. as chlorid, carbonate, or sulfate	Apple-green	7.20
Strontium.	In O. as chlorid, carbonate, or sulfate immediately, or after a while,	Carmine-red	11
	obliterated by baryta		
Calcium.	In O. as chlorid, carbonate, fluorspar	Brick-red	7.12
	as gypsum or sulfate at first	Light yellow	7
	and after a little time the flame colors	Light red	10
	Phosphate and borate of lime color flame	Green	20
Magnesium.	Salts heated leave the flame	Colorless	1
	Heated to redness in O. and then applying nitrate of cobalt, reheating, and calcining colors mineral	Flesh-red	
Glucinium.	Powdered and heated by O. on Ch. and then moistened with nitrate of cobalt and reheated colors mineral	Dark gray	4
Aluminium.	Heating in O. to redness, moistening with nitrate of cobalt, reheating to redness, but avoiding fusion, then after cooling the mineral is	Blue	14
Manganese.	A trace in O. in a mixture of 1 part saltpetre and 2 parts soda	Transparent	
	on platinum foil colors assay, hot,	Green	20
	on cooling becomes opaque and	Bluish green	13.20
	With a mixture of saltpetre and carbonate of potash a mass is formed which dissolved in water produces a solution colored	Dark green	21
	In O. with borax on platinum loop, hot,	Violet	23
	deepening when Mn is increased to	Black	6
	In R. the borax bead becomes	Colorless	1
Iron.	In small quantity, in O., with borax on platinum loop, hot,	Red	11
	by increasing quantity	Dark red	12
	on cooling according to quantity,	Yellow	8
		to dark yellow	9
	In R. the borax bead becomes cold	Bottle-green	4.20
	Ferric thiocyanate solution	Intense red	11
Chromium	In O. with borax on platinum loop, hot	Yellow	8
	In larger quantity the bead, hot	Dark red	12
	The same borax bead when cold	Yellowish green	7.20
	In R. the borax bead, hot and cold,	Green	20
	In O. with salt of phosphorus on platinum loop the bead hot transparent	Reddish	10
	After cooling fine	Green	20

Note.—The numbers in the last column refer to the table of color and lustre. 24e.

METALS AND OXIDS IN FLAME—(*Continued*)

Cobalt.	In O. and in R with borax on platinum loop, hot and cold,	Blue	14
	With carbonate of soda in platinum-wire loop in O a mass colored	Reddish	10
	Same in R on Ch a mass colored reduced to powder, magnetic[1]	Gray	4
Nickel.	In O with borax on platinum-wire loop if quantity is small, hot,	Violet	23
	On cooling the bead become	Reddish brown	10.17
	In R the bead becomes cloudy, opaque,	Gray	4
	In R. on charcoal reduced to a spongy mass, subject to magnetic attraction		
	In R on Ch with carbonate of soda reduced to metal as white bright scales attracted by magnet		
	In R with addition of a little tin and continued blowing on Ch a metallic globule of nickel-tin is formed and the glass bead is	Colorless	1
	In O in small quantity with phosphorus salt the bead, hot, is	Reddish brown	10.17
	After cooling the color becomes	Yellowish	7
	With increased quantity hot,	Brown	17
	and when cold the bead becomes	Yellowish brown	8.17
Antimony.	In O. on Ch. fuses easily, evaporates to antimonous acid, coating Ch	White	2
	which touched on edge with ammonium sulphid colors the edge	Reddish orange	
	In R. on asbestos thread, color flame	Greenish white	
Lead.	In O on Ch. forms a sublimate colored	Yellow	8
	In R this sublimate colors flame	Bluish	13
	In R. on Ch with soda red to metal		
	In O. with borax the glass, hot, is	Limpid yellow	8
	This bead on cooling becomes	Colorless	1
	except by a large addition of oxid, color	Yellow	
	In R. on Ch the borax bead is diffused and with continued blowing the oxid is reduced to metal and the bead again becomes	Colorless	1
	Finely powdered, moistened with hydrochloric acid on an asbestos thread in O tinges flame	Bluish	
Bismuth.	In O. or R. on Ch. is reduced to metal, which ultimately evaporates, leaving a coating colored	Yellow	8
	In O. or R on Ch with soda reduced to metal		
	In O. with borax, depending on quantity of oxid dissol'd, the bead, hot	Yellow to Yellowish red	8 7.10
	cold	Colorless to Yellow	1 6
	From bismuth salt solutions a bismuth powder can be precipitated by iron, copper, and zinc	Black	
	In B. this powder melts to a globule of metal, very brittle, the fracture colored	Roseate	2.10
	In R. on Ch. a borax glass at first becomes	Gray	
	and cloudy. The oxid is reduced to metal with effervescence and the borax bead again becomes	Colorless	

[1] Some powder is attracted by a magnet.

METALS AND OXIDS IN FLAME—(*Continued*).

Zinc.	In O the metal fuses and burns with flame. On Ch a sublimate forms, luminous while hot, becoming on cooling	Yellow Yellow White	8 8 2
	In R. on Ch. with carbonate of soda is formed a mass colored hot, which on cooling becomes	Yellow White	
	In O, heated and moistened with nitrate of cobalt, heated to redness is The mineral on cooling becomes	Yellowish green Green	7.20 20
	In O borax bead on platinum loop, hot in small quantity on cool'g becomes for large quantity, on cooling, color	Yellowish Colorless White	7 1
Cadmium.	In R. on Ch. is absorbed, on cooling forms sublimate.	Reddish brown	10.17
	In O. with borax on platinum loop, while hot, forms a limpid glass, which on cooling is almost and with much oxid after cooling	Yellowish Colorless White	7 1 2
Tin.	In O on Ch. burns to oxid with a luminous flame, the oxid on cooling colors to	Yellowish Gray white	7 3.2
	The sublimate formed is close to assay		
	In R. on Ch. with soda a metal bead is formed Add saltpeter for small quantities of tin		
	Borax beads in O and R., hot and cold, are	Colorless	1
Uranium.	In O. on Ch. infusible color of mineral	Yellowish green	7.20
	In R. on Ch. color of mineral	Black	6
	In O. and R on Ch. with carbonate of soda in proper amount may form a mass	Yellowish brown	7.17
	If soda is in excess then mass is obsorbed in Ch.		
	In O. with borax on platinum wire loop the bead will be, while hot, varying with quantity of oxid, cold	Yellow to dk. red Colorless to dark Yellow	8, 12 1–9
	In O. with salt of phosphorus on platinum-wire loop the glass will be, hot cold	Yellow Yellowish green	8 7.20
	In R. the phosphorus bead will be, hot cold	Grayish green Fine green	3.20 20
	In R. on Ch. with a little tin	Dark green	21
Molybdenum.	In R. on platinum as acid, oxid, or sulphid the flame is colored	Bright green	19.20
	With microcosmic salt in Pt loop in O in R.	Yellow Green	8
Copper.	In O. with borax on Pt loop, hot, cold,	Green Blue	20 14
	In R. with borax on Pt loop, cold,	Red	11
	In R. on Ch. with carbonate of soda reduced to metallic globules		
	Powdered, moistened with HCl, on platinum wire in lower part of Bunsen flame, colors flame near wire above wire	Blue Green	14 20
Mercury.	In R. on Ch. or other support volatile		

METALS AND OXIDS IN FLAME—(*Continued*).

Silver.	In O. on Ch. by protracted blowing forms incrustation	Reddish brown	10.17
	In R. on Ch. with soda, metallic globule		
	In O. on Ch. or a support of white-burned clay or porcelain, when pure the flame is	Colorless	1
	With $\frac{1}{300000}$ of impurity of iron, copper, or silicium, the surface of the melted silver bead is covered by a strong, very mobile scum and the impurity colors the flame		
Gold.	In O or R on Ch., with or without soda, reduced to metal. Soda passes into Ch		
Platinum.	Unalterable and infusible		
Paladium.	With sulphur fusible, alone infusible		
Iridium.	In O or R on Ch., with or without soda, reduced to metal which is infusible		
Titanium.	In R. with phosphorus salt, a globule, hot,	Yellow	8
	is with difficulty obtained it is cold	Violet-blue	22.14
Rhodium.			
Tellurium.	In O. and R. on Ch., sublimate close to assay	White edged	2
	by O moved from place to place, becomes	Yellow-brown	8.16
	In R. the sublimate colors flame	Green	20
Selenium.	In O and R on Ch. fuses evaporates, odor	Horseradish	
	The fumes of volatilization colored	Brown	17
	By O. the sublimate formed colored	Steel-gray	3.13
	can be moved from place to place	Edge dull violet	3.22
	In R. the sublimate colors flame	Blue	14
Arsenic.	In O. and R. on Ch. evaporates, emits odor	Alliaceous	
	At some distance from assay is formed a sublimate	White, edge gray	2–4
	which, touched by R., colors flame	Pale blue	13
Osmium.	In O it oxidizes into osmic acid, emitting a pungent smell and affecting the eyes	Osmic odor	
	Colors flame of alcohol	Bright white	2
	In R on Ch reduced to metal powder	Dark brown	18
Sulphur.	Burns to sulphurous acid with odor	Sulphurous	
	and with a flame colored	Blue	13
	In O on Ch with a mixture of 2 parts soda and 1 part borax fuses into a mass which, transferred to a bright silver surface and moistened, produces thereon a spot colored	Black	6
Thallium.	In closed tubes melts forming vitreous	Brownish red	16 14
	slag around the fused globule, cold	Yellowish	7.16
	On Ch. by B emits dense fumes streaked	White and brown	2–17
	The point and edge of flame is	Emerald green	20
	On thin porcelain the deposit is	Brown-black	17 6
	and the appearance of the flame	Brownish	16
Vanadium.	In O with borax the bead colors	Green	20
	In R. the bead becomes	Colorless	1

29. Alphabetical List of Minerals.

Ref. No.	Name	Symbol	Ref. No.	Name	Symbol
142	Acadialite	Si	8	Asparagus-stone	Ca
118	Achroite	Si	9	Asphaltum	C
9	Acmite	Mg	13	Atacamite	Cu
62	Actinolite	Si	52	Augite	Si
36	Adular	Si	4	Auriferous pyrites	Au
2	Agaric mineral	Ca	4	Auripigmentum	As
10	Agate	Si	3	Autunite	U
31	Aikinite	Pb	6	Aventurine	Si
9	Alabandite	Mn	129	Axinite	Si
9	Alabaster	Ca	8	Azurite	Cu
9	Albite	Na			
11	Alexandrite	Al	9	Babingtonite	Mg
	Algodonite	Cu	1	Barite	Ba
7	Allagite	Mn	4	Baryta	Ba
116	Allanite	Si	4	Barytocalcite	Ba
80	Almandite	Si	21	Basanite	Si
9	Altaite	Pb	2	Basic flucerine	Ce
21	Alum	Al	8	Bauxite	Al
1	Alumina	Al	12	Berengelite	C
19	Aluminate	Al	4	Berthierite	Sb
19	Alum-stone	Al	69	Beryl	Si
19	Alumite	Al	76	Beryllonite	Si
3	Amalgam	Hg	15	Biotite	Mg
36	Amazon-stone	Si	1	Bismuth	Bi
11	Amber	C	2	Bismuthinite	Bi
17	Amblygonite	Al	3	Bitter spar	Mg
4	Amethyst	Si	8	Bitumen	C
4	Amethyst oriental	Al	4	Bituminous coal	C
11	Amyanthus	Mg	2	Blacklead	C
60	Amphibole	Si	1	Black-jack	Zn
38	Amphodelite	Si	12	Black copper	Cu
140	Analcite	Si	1	Blende	Zn
2	Anatase	Ti	16	Blood-stone	Si
125	Andalusite	Si	6	Blue-john	Cu
82	Andradite	Si	14	Blue vitrol	Cu
7	Anglesite	Pb	7	Bog-iron ore	Fe
10	Anhydrite	Ca	6	Bog manganese	Mn
4	Ankerite	Mg	7	Boracite	Mg
38	Anorthite	Si	105	Boltonite	Si
3	Anthracite	C	2	Borax	Na
2	Antimonite	Sb	3	Bornite	Cu
1	Antimony	Sb	1	Bort	C
2	Antimony glance	Sb	2	Boulangerite	Pb
8	Apatite	Ca	3	Bournonite	Pb
13	Aphrodite	Mg	8	Branchite	C
4	Apophyllite	K	3	Braunite	Mn
70	Aquamarine	Si	3	Breithauptite	Ni
3	Aragonite	Ca	9	Breislakite	Mg
9	Arfvedsonite	Mg	5	Breunerite	Mg
1	Argentiferous galena	Pb	98	Brittle mica	Si
2	Argentite	Ag	14	Brochantite	Cu
3	Arkansite	Ti	56	Bronzite	Si
1	Arsenates	As	3	Bromlite	Ba
4	Arsenides	Fe	3	Brookite	Ti
5	Arsenical antimony	Sb	6	Brown coal	C
5	Arsenious acid	As	1	Brucite	Mg
5	Arsenolite	As	12	Bustamite	Mn
4	Arsenopyrite	Fe			
65	Asbestos	Si	25	Cachalong	Si

Note. — The reference number and the chemical symbol refer to Tables 30.

Alphabetical List of Minerals—*Continued*

Ref. No.	Name	Symbol	Ref. No.	Name	Symbol
0	Cadmium	Cd	122	Cordierite	Si
3	Cairngorm stone	Si	11	Cornelian	Si
5	Calamine	Zn	1	Corundum	Al
1	Calcite	Ca	39	Couzeranite	Si
2	Calc spar	Ca	14	Crichtonite	Fe
46	Cancrinite	Si	67	Crocidolite	Si
5	Cannel coal	C	10	Crocoite	Pb
1	Capillary pyrites	Ni		Crookesite	Se
0	Carbon	C	133	Cross-stone	Si
2	Carbonate of lime	Ca	12	Cryolite	Al
9	Carnelian	Si	6	Cuprite	Cu
1	Cassiterite	Sn	126	Cyanite	Si
91	Cat-gold	Si			
91	Cat-silver	Si	4	Danaite	Co
7	Cat's-eye	Si	87	Danalite	Si
1	Celestite	Si	121	Danburite	Si
5	Cerargyrite	Ag	132	Datholite	Si
116	Cerine	Si	20	Dawsonite	Al
6	Cerite	Ce	82	Demantoid	Si
0	Cerium	Ce	12	Descloizite	Pb
6	Cerusite	Pb	149	Desmine	Si
141	Chabazite	Si	50	Diallage	Si
14	Chalcanthite	Cu	1	Diamond	C
9	Chalcedony	Si	7	Diaspore	Al
2	Chalcocite	Cu	48	Diopside	Si
4	Chalcopyrite	Cu	10	Dioptase	Cu
2	Chalk	Ca	112	Dipyre	Si
8	Chalybite	Fe	128	Disthene	Si
20	Chert	Si	1	Dog-tooth spar	Ca
124	Chiastolite	Si	3	Dolomite	Mg
22	Childrenite	Fe	6	Dry bone	Zn
12	Chiolite	Al	13	Dyclasite	Ca
8	Chlor-apatite	Ca	8	Dysodile	C
5	Chlorite	Mg			
6	Chlorophane	Ca	5	Eisenrose	Fe
131	Chondrodite	Si	45	Elæolite	Si
10	Chromic iron	Fe	71	Emerald	Si
1	Chromite	Cr	10	Emerald copper	Cu
11	Chrysoberyl	Al	6	Emery	Al
9	Chrysocolla	Cu	11	Enargite	Cu
14	Chrysolite	Mg	54	Enstatite	Si
15	Chrysoprase	Si	22	Eosphorite	Fe
26	Cimolite	Al	115	Epidote	Si
2	Cinnabar	Hg	8	Epsom salt or	Mg
84	Cinnamon-stone	Si	8	Epsomite	Mg
4	Clausthalite	Si	3	Erubescite	Cu
14	Clay	Al	5	Erythrite	Co
11	Cleveit[1]	Ca	85	Essonite	Si
102	Clinochlore	Si		Eucarite	Se
102	Clintonite	Si	73	Euclase	Si
0	Coal	C	88	Eulyte	Si
5	Cobalt bloom	Co	6	Euxite	Y
3	Cobaltine	Co			
51	Coccolite	Si	5	Fahlerz	Cu
13	Colemanite	Ca	1	False galena	Zn
15	Colestine	Fe	1	False lead	Zn
24	Columbite	Fe	1	False topaz	Si
1	Copper	Cu	2	Feather ore	Pb
12	Copperas	Fe	35	Feldspar	Si
2	Copper glance	Cu	4	Fergusonite	Y
4	Coracite	U	26	Fettbol	Al

[1] 1 gramme cleveit gives 7 c.c. helium gas.

Alphabetical List of Minerals—*Continued.*

Ref. No	Name	Sym-bol	Ref No.	Name	Sym-bol
129	Fibrolite	Si	11	Heterosite	Mn
8	Fichtelite	C	149	Heulandite	Si
26	Fire opal	Si	53	Hornblende	Si
1	Flêches d'amour	Ti	5	Horn quicksilver	Hg
18	Flint	Si	5	Horn silver	Ag
3	Flossfern	Ca	19	Hornstone	Si
2	Flucerine	Ce	3	Horse-flesh ore	Cu
8	Fluor-apatite	Ca	52	Hudsonite	Si
6	Fluorite	Ca	134	Humite	Si
6	Fluorspar	Ca	12	Huraulite	Mn
10	Foliated talc	Mg	106	Hyacinth	Si
9	Forsterite	Mg	32	Hyalite	Si
8	Fossil copal	C	40	Hyalophane	Si
9	Franklinite	Fe	15	Hydraulic limestone	Ca
			25	Hydrophane	Si
3	Gadolinite	Y	55	Hypersthene	Si
3	Gahnite	Zn	14	Hystatite	Fe
1	Galena	Pb			
77	Garnet	Si	1	Iceland spar	Ca
5	Garnierite	Ni	93	Ichthyophthalmite	Si
114	Gehlite	Si	114	Idocrase	Si
4	Genthite	Ni	8	Idrialine	C
28	Geocronite	Pb	14	Ilmenite	Fe
33	Geyserite	Si	118	Indicolite	Si
9	Gibbsite	Al	34	Infusorial earth	Si
26	Girasol	Si	6	Iodic mercury	Hg
6	Glauber salt	Na	122	Iolite	Si
39	Glaucolite	Si	1	Iridium	Ir
8	Glauberite	Na	2	Iridosmine	Ir
4	Glaucodot	Co	2	Iron pyrites	Fe
145	Gmelinite	Si	14	Iserine	Fe
11	Goethite	Fe	8	Ixolyte	C
1	Gold	Au			
2	Gold tellurid	Au	63	Jade	Si
61	Grammatite	Si	64	Jadeite	Si
2	Graphic tellurium	Au	2	Jamesonite	Pb
2	Graphite	C	24	Jarosite	Fe
26	Grappite	Al	17	Jasper	Si
2	Gray antimony	Sb	30	Jasper opal	Si
5	Gray copper	Cu	52	Jeffersonite	Si
1	Greenokite	Cd	6	Jet	C
77	Grenat	Si	105	Job's-tears	Si
78	Grossularite	Si	5	Johannite	U
12	Guaquillite	C			
9	Gypsum	Ca	14	Kaolin	Al
			14	Kaolinite	Al
4	Haidingerite	Sb	123	Keilhauite	Si
1	Halite	Na	11	Kerolite	Mg
27	Harlequin opal	Si	4	King's-yellow	As
147	Harmotome	Si	123	Kilbrickenite	Si
8	Hartite	C	26	Kollyrite	Al
8	Hatchettine	C	8	Konlite	C
4	Hausmannite	Mn			
	Hayne	Si	39	Labradorite	Si
144	Haydenite	Si	39	Labrador feldspar	Si
2	Heavy spar	Ba	43	Lapis lazuli	Si
52	Hedenbergite	Si	10	Lapis ollaris	Mg
16	Heliotrope	Si	39	Latrobite	Si
86	Helvite	Si	150	Laumonite	Si
5	Hematite	Fe	16	Lazulite	Al
75	Herderite	Si	0	Lead	Pb
85	Hessonite	Si	5	Lehrbachite	Se

Alphabetical List of Minerals—(*Continued*).

Ref No.	Name	Symbol	Ref. No.	Name	Symbol
11	Lepidokrokite	Fe	9	Moss-agate	Si
1	Lepidolite	Li	66	Mountain cork	Si
93	Lepidomelane	Si	66	Mountain leather	Si
41	Leucite	Si	32	Muller's glass	Si
4	Leucopyrite	Fe	3	Muscovite	K
15	Libethenite	Cu	91	Muscovy glass	Si
76	Lignite	C	15	Myargyrite	Ag
0	Lime	Ca			
2	Limestone	Ca	3	Nagyagite	Au
7	Limonite	Fe	10	Natrolite	Na
1	Linnæite	Co	3	Natron	Na
24	Liroconite	Cu	10	Needle zeolite	Na
1	Lithia mica	Li	19	Nemalite	Mg
3	Lithiophilite	Li	44	Nephelite	Si
25	Lollinginite	Fe	65	Nephrite	Si
1	Love's-arrows	Ti	2	Niccolite	Ni
37	Loxoclase	Si	0	Nickel	Ni
1	Lumachelle	Ca		Nosean	Si
22	Lydian stone	Si	109	Nuttalite	Si
124	Macle	Si	2	Octahedrite	Ti
12	Magnesia	Mg	7	Ochre, brown	Fe
2	Magnesite	Mg	5	Ochre, red	Fe
6	Magnetic iron ore	Fe	151	Oligoclase	Si
1	Magnetic pyrites	Fe	16	Olivenite	Cu
6	Magnetite	Fe	104	Olivine	Si
7	Malachite blue	Cu	12	Onyx	Si
7	Malachite green	Cu	25	Opal	Si
12	Malacolite	Cu	27	Opal allophane	Al
26	Malthacite	Al	11	Ophiolite	Mg
0	Manganese	Mn	108	Orangite	Si
9	Manganblende	Mn	2	Oriental ruby	Al
7	Manganese spar	Mn	3	Oriental sapphire	Al
2	Manganite	Mn	5	Oriental topaz	Al
2	Marble	Ca	4	Orpiment	As
3	Marcasite	Fe	116	Orthite	Si
98	Margarite	Si	2	Orthoclase	K
113	Marialite	Si	100	Ottrelite	Si
11	Marmolite	Mg	83	Ouvarovite	Si
13	Meerschaum	Mg	8	Ozocerite	C
111	Meionite	Si			
82	Melanite	Si	13	Pachnolite	Al
18	Melanschroite	Pb	1	Paladium, native	Pd
12	Melanterite	Fe	60	Pargasite	Si
14	Menaccanite	Fe	3	Peacock copper	Cu
25	Menilite	Si	99	Pearl mica	Si
1	Mercury	Hg	1	Pearl spar	Mg
6	Messitine	Mg	135	Pectolite	Si
4	Metacinnabarite	Hg	10	Pencil stone	Mg
90	Mica	Si	103	Penninite	Si
16	Microline	Ca	6	Pentlandite	Ni
16	Microlite	Ca	14	Peridot	Mg
8	Middletonite	C	15	Perovskite	Ca
28	Milk opal	Si	10	Petroleum	C
1	Millerite	Ni	5	Petzite	Au
5	Mimetite	Pb	143	Phacolite	Si
1	Mispickel	As	12	Pharmacolite	Ca
31	Mohawkite	Cu	17	Pharmacosiderite	Fe
1	Molybdenite	Mo	74	Phenacite	Si
0	Molybdenum	Mo	148	Phillipsite	Si
1	Monazite	Ce	94	Phlogopite	Si
36	Moonstone	Si	26	Pholerite	Al

Alphabetical List of Minerals—(*Continued*).

Ref. No.	Name	Symbol	Ref. No.	Name	Symbol
7	Photizite	Mn	3	Red sulphuret of arsenic	As
8	Piauzite	C	4	Red zinc ore	Zn
11	Picrolite	Mg	29	Resin mineral	Si
101	Pinite	Si	12	Retinite	C
1	Pitchblende	U	8	Rhodochrosite	Mn
37	Plagioclase	Si	7	Rhodonite	Mn
2	Plagionite	Pb	2	Rock crystal	Si
1	Plasma	Si	2	Rock meal	Ca
9	Plaster-of-Paris	Ca	2	Rock milk	Ca
1	Platinum	Pt	1	Rock salt	Na
4	Platinum-iridium	Pt	26	Rock soap	Al
2	Plumbago	C	5	Roselite	Co
91	Plumose mica	Si	26	Rosite	Al
1	Polianite	Mn	5	Rosequartz	Si
8	Polycrase	Y	2	Rubellite	Li
1	Polydymite	Ni	2	Ruby, balas	Al
52	Polylite	Si	2	Ruby, oriental	Al
7	Polymignite	Y	4	Ruby, silver	Ag
0	Potassium	K	10	Ruby, spinel	Al
10	Potstone	Mg	1	Rutile	Ti
1	Potter's ore	Pb			
14	Prase	Si	49	Sahlite	Si
80	Precious garnet	Si	5	Saltpeter	K
25	Precious opal	Si	18	Samarskite	Fe
11	Precious serpentine	Mg	36	Sanidine	Si
133	Prehnite	Si	6	Sapolite	Mg
4	Proustite	Ag	3	Sapphire	Al
5	Psilomelane	Mn	9	Sard	Si
3	Pucherite	Bi	13	Sardonyx	Si
3	Purple copper ore	Cu	1	Satin spar	Ca
22	Pyenite	Al		Saussurite	Si
3	Pyrargyrite	Ag	109	Scapolite	Si
2	Pyrite	Fe	11	Scheelite	Ca
4	Pyrites, arsenical	Fe	8	Schererite	C
4	Pyrites, auriferous	Au	15	Schiller-spar	Mg
1	Pyrites, capillary	Ni	9	Schorlomite	Y
2	Pyrites, cockscomb	Fe	27	Schroetterite	Al
4	Pyrites, copper	Cu	139	Scolecite	Si
2	Pyrites, iron	Fe	19	Scorodite	Fe
1	Pyrites, magnetic	Fe	102	Seibertite	Si
2	Pyrites, spear	Fe	7	Selenid of mercury	Hg
3	Pyrites, white iron	Fe	9	Selenite	Ca
2	Pyrochlore	Th	1	Selenium	Se
1	Pyrolusite	Mn	3	Senarmontite	Sb
4	Pyromorphite	Pb	13	Sepiolite	Mg
79	Pyrope	Si	11	Serpentine	Mg
128	Pyrophyllite	Si	8	Siderite	Fe
116	Pyrorthite	Si	1	Silex	Si
1	Pyrrhotite	Fe	1	Silica	Si
47	Pyroxene	Si	33	Silicious sinter	Si
			24	Silified wood	Si
1	Quartz	Si	127	Sillimanite	Si
1	Quicksilver	Hg	1	Silver	Ag
13	Quincite	Mg	2	Silver glance	Ag
			5	Silver horn	Ag
3	Realgar	As	4	Silver ruby	Ag
6	Red antimony	Sb	2	Smalt	Co
6	Red copper ore	Cu	2	Smaltite	Co
5	Red hematite	Fe	60	Smaragdite	Si
5	Red iron ore	Fe	26	Smelite	Al
5	Red ochre	Fe	6	Smithsonite	Zn
4	Red silver	Ag	3	Smoky quartz	Si

Alphabetical List of Minerals.—(*Continued*)

Ref. No.	Name	Symbol
10	Soapstone.	Mg
0	Soda.	Na
42	Sodalite.	Si
5	Soda nitre.	Na
0	Sodium.	Na
8	Spathic iron.	Fe
3	Spear pyrites	Fe
5	Specular iron.	Fe
2	Sperrylite.	Pt
81	Spessartite.	Si
1	Sphalerite.	Zn
124	Sphene.	Si
14	Spiegeleisen.	Mn
10	Spinel	Al
57	Spodumene.	Si
14	Stalactite	Ca
14	Stalagmite.	Ca
2	Stannite	Sn
130	Staurotite	Si
10	Steatite.	Mg
6	Stephanite	Ag
2	Stibnite.	Sb
146	Stilbite	Si
1	Stream-tin	Sn
2	Strontianite.	Sr
0	Strontium.	Sr
1	Sulphur	S
2	Sylvanite.	Au
1	Sylvite.	K
59	Tabular spar.	Si
10	Talc.	Mg
16	Tantalite.	Fe
1	Tellurium.	Te
5	Tennantite.	Cu
12	Tenorite.	Cu
5	Tetrahedrite.	Cu
6	Thenordite.	Na
13	Thomsenolite	Al
137	Thomsonite.	Si
1	Thorite.	Th
8	Tiger's-eye	Si
0	Tin.	Sn
1	Tin stone.	Sn
2	Tin pyrites	Sn
1	Tin oxid	Sn
14	Titanic iron.	Fe
123	Titanite.	Si
0	Titanium.	Ti
1	Toad's-eye tin.	Sn
120	Topaz	Si
82	Topazolite.	Si
2	Torbernite.	U
24	Touchstone.	Si
118	Tourmaline.	Si
61	Tremolite.	Si
0	Tridymite.	Si
21	Triphilite.	Fe
11	Triplite.	Mn
4	Trona.	Na
4	Troostite	Zn

Ref. No.	Name	Symbol
13	Turgite.	Fe
1	Turnerite.	Ce
15	Turquois.	Al
6	Tile ore.	Cu
14	Ulexite	Ca
9	Ultramarine.	Co
1	Uraninite	U
0	Uranium.	U
3	Uranium mica.	Zn
83	Uvarovite.	Si
8	Vanadinite.	Pb
11	Verd-antique.	Mg
97	Vermiculite.	Si
2	Vermilion.	Hg
114	Vesuvianite.	Si
23	Vivianite.	Fe
6	Wad.	Mn
16	Wavellite	Al
110	Wernerite.	Si
2	Wheel ore.	Fe
8	White antimony	Sb
5	White arsenic.	As
6	White lead.	Pb
4	Willemite	Zn
3	Witherite	Ba
28	Woerthite.	Al
3	Wolfram.	W
20	Wolframite	Fe
59	Wollastonite.	Si
32	Wood opal.	Si
1	Wood tin.	Sn
2	Wulfenite.	Mo
1	Xenotine.	Y
4	Yellow sulphuret of arsenic.	As
2	Yttriocerite.	Y
5	Yttriocolumbite.	Y
	Yttriotitanite	Y
136	Zeolite	Si
0	Zinc.	Zn
1	Zinc-blende.	Zn
6	Zinc carbonate.	Zn
4	Zinc ore, red	Zn
2	Zinc oxid.	Zn
4	Zinc silicate.	Zn
1	Zinc sulphid.	Zn
6	Zinc spinel.	Zn
2	Zincite.	Zn
106	Zircon.	Si
	Zirconium	Zr
117	Zoisite.	Si
6	Zorgite.	Se
89	Zungite.	Si

30. TABLES OF MINERAL CHARACTERISTICS.

The names of the minerals in these tables are classified in accordance with the occurrence in the mineral of the metal or metalloid forming the principal constituent thereof

In the chemical formulas, where figures are at the lower right-hand side of the chemical symbol, the latter should be considered as expressing in addition to the substance or chemical element also its atomic weight, while the symbols with in-

MINERAL

H_2O = One Atomic Weight of Water.

References for Explanation			24a	24c	24d	24f	24e
Reference Number.	Name of Mineral	Chemical Formula or Composition of Pure Mineral	Condition. Structure	Lustre, Color	Crystalline System	Fracture	Color of Streak
0	Iron	Fe, At. wt. 56	ab 1	a 3 13		5	
1	Pyrrhotite	Fe_7S_8	f 1	a 7, 17	V		5-6
2	Pyrite	FeS_2	f 1	a 7	I		9, 21-6
3	Marcasite	FeS_2.	f 1	a 7	V		
4	Arsenopyrite	FeS_2FeAs_2.	f 1	a 2	V		5-6
5	Hematite	Fe_2O_3.	f 1	a 5-6 .	IV		12..
6	Magnetite	Fe_3O_4	f 1	a 6	I		6
7	Limonite	$2(Fe_2O_3)3(H_2O)$	14-1	j 18	IV	5	7 17
8	Siderite	$FeCO_3$.	f 4-1	c 18, 11		2	2
9	Franklinite	$(FeZnMn)O_x$ or $2(FeMn)O_3$	f 1	6	I	3	10.18
10	Chromite	$FeCr_2O_4$.	.f 1	ca 18, 6	I.	.4.	. 18..
11	Goethite	$Fe_2O_3 + H_2O$	1	17			16.8
12	Copperas	$FeSO_4$.	f 1	c 19.4	VI	2	
13	Turgite	$2(Fe_2O_3)H_2O$.					12
14	Ilmenite	$FeTiO_3 + MgTiO_3$	2	a 6	IV		
15	Columbite	$FeNbO_x$	. f 1	ah 6	V.	.2.	.10.18.
16	Tantalite	$FeTaO_3$.					
17	Pharmacosiderite	$FeAsO_3 + H_2O$		8, 20	I		
18	Samarskite	$FeTaNbCeYO_x$					
19	Scorodite	$FeAsO_4 + H_2O$		c 19, 10 17	V		2 .
20	Wolframite	$FeWO_3$	1.	. aj 5-6	VI		.10.18.
21	Triphylite	$FeLiPO_4$.	1	19.4		2	
22	Childrenite	$FeAlPO_5 + H_2O$.	1	7 17	V	2	
23	Vivianite	$FePO_4 + H_2O$	16	c 15-20	VI	2	13
24	Jarosite	$3(Fe_2O_3)(SO_3)_4K_2O + 6(H_2O)$					
25	Lollinginite	$FeAs_2$					.....
0	Lead	Pb, At. wt 206	a 1	.ac 3 13			...
1	Galena	PbS	f 21	a 5	I	3 2	5
2	Jamesonite	$3(PbS) + Sb_2S_3$.	7 6	13.4	V		13.4
3	Bournonite	$3(PbCu)S + Sb_2S_3$		13.4	V		13.4
4	Pyromorphite	$3(Pb_3P_2O_8)PbCl_2$	f	d 20, 17	III		2
5	Mimetite	$PbAsO_3$		d 16, 17	III	.	....

* Optic Electric Magnetic Taste Odor Solution

definite indices, as x, y, z, mean that the substance or mineral is composed of the elements indicated by the symbols, but in undetermined proportions

For instance, in the mineral magnetite, Fe_3O_4, the symbols and indices indicate that the mineral is composed of 3×56 iron and 4×16 oxygen, or 168 parts by weight of iron and 64 parts oxygen, while FeO_x would mean that the mineral is composed of iron and oxygen in undetermined proportions.

CHARACTERISTICS

O=Oxidiz g; R=Reduc'g fl.; H—Hot; C=Cold.

	24f	24b	24c	25	24e	26, 24e		27, 24e			28, 24e			
Reference Number	Op., E., M., T., Od., S.*	Hardness	Specific Gravity	Acids		Heat, Candle, Gas, or Blowpipe Flame'								
				Action on Mineral	Color of Sol. or of Precipitate	Change of Mineral	Color of Flame or of Mineral	Changes in Tubes			Borax and Phosphate Beads, and Sublimate on Charcoal			
								Action †	Color c p‡		O		R	
									H	C	H	C	H	C
0	f		7 9	h′s′′s$_1^7$n										
1		4	4 6	h³		13		c 5	18	8				
2		6	5			13		2	18	8				
3		6	4.8											
4		6	6			13								
5	.	6	5.2	......	...	.. 7	..		..		.11, 17.	..8..	...	..20....
6	f	6	5 1			7								7.20
7		5	4			13	6	5		1				20
8	b	4	3.8	$h^2\ s^2\ n^2$		13-7	6							20
9						7					e 2	23		e 7.21
	f	6	5.8											
10	..f..	5.5	.4.4	......	....	....7..	.....	.		..	......	..20..	....	......
11		5	4.1					5						
12	b3C	2	1.8			13						20		
13						11		5						
14	f	5	4.8			7								
15	...	5.5	.6	......	....	....7..	......	..		..	......	..21..	....	......
16	-													
17														
18		5.5	5.5											
19	b	3.8	3.2											
20	..	5.3	.7.3	......	....	....6..	.. .	.	..	.	......	'12,20	....	......
21		5	3.8											
22		1.7	2.7											
23	abg	1.7	2.7			20		5		1				
24	.													
25	..	.	..	.....	....	... .	...	.		.	......	....	....	......
0	...	.	11.4	..n_1	...	1, 2..	.				. .	....	....	......
1	8	2.5	5.7			15.11					e 8 f 2			
2		2.5	5.7											
3		2.8	5.8								e 8 f 2			
4	a.b	3.8	6.8			21	'							.
5	...	3 .	.6.5	......	...	..19	. ..				e 8 f 2.	....	....	......

† Action on mineral. ‡ Color of condensed part.

MINERAL

References for Explanation			24a	24c	24d	24f	24e
Ref. No.	Name of Mineral	Formula or Composition of Pure Mineral	Cond Stretr	Lustre, Color	Cryst System	Fracture	Color of Streak
6	Cerusite	$PbCO_3$	f 1	2–3	V		2–3
7	Anglesite	$PbSO_4$	f 18, 3, 1	bc 2.3.19	V		
8	Vanadinite	$PbVO_3$		d 8, 10.17	III	2	
9	Alatite	PbTe		3.2		2	
10	Crocoisite	$PbCr_2O_4$	..1...	...11	VI	.	..9..
11	Descloisite	$PbCuZnV_4O_x$					
12	Ceracite	PbCl		e 2, 7, 10			
13	Corneous lead	$PbClPbCO_3$					
14	Lead molybdate	$(PbO)_2MoO_2$	1	d 3 8	I		
15	Lead selenate	$PbSeO_x$	......	8 ..	.II.	..	....
16	Lead tungstate	$PbWO_4$		d 20, 17, 11	II		
17	Plumboresinite	$PbAl_4O_7 + 6H_2O$	15	d 8, 10 17			
18	Melanochroite	$Pb_3Cr_2O_9$		12			8.11
19	Vauquelinite	$5(PbCu)2(CrP_2O_7)$	16 1				
20	Caledonite	$PbCuCO_4PbSO_3$	......	..13.20	.	..	......
21	Cuproplumbite	$PbS\ Cu_2S$					
22	Foliated tellurium	$Pb_{11}Te_6Au$	4	5			
23	Minium	Pb_3O_4	10	11			
24	Feather ore	Pb_2SbS_3	7	5			
25	Boulangerite	Pb_3SbS_3	.. 7 .	. .13.4.		.	......
26	Plagionite	$Pb_6Sb_5S_{10}$	f	5	VI		
27	Zinkenite	$Pb_4Sb_6S_9$	7.1	13.3	III		
28	Geocronite	Pb_5SbS_4	18 1	3			
29	Kobellite	$Pb_6SbBi_2S_{10}$	9				
30	Steinmannite	$Pb_xSb_yS_z$	...1..	....	I	.2.	.....
31	Aikinite	$PbCuBiS_3$					
32	Clausthnlite	PbSe					
0	Copper	Cu, At. wt. 63.4	ab 1	a 16.12	I		
1	Native copper	Cu	..ab 1..	..9.12. .	.		.....
2	{ Chalcocite. / Redruthite. }	Cu_2S	fc 1	a 5, 6	V		5, 6
3	{ Bornite. / Erubescite. }	Cu_3FeS_3	f 1	16.11	I		3 6
4	Chalcopyrite	$CuFeS_2$	f 1	9	I		20, 6
5	Tetrahedrite	$4(Cu_2S)Sb_2S_3$	..f 1..	5	. I	2.	.5 .
6	Cuprite	Cu_2O	f 10.1	ab 12	I	2	16.11
7	Malachite	$Cu_2CO_4 + H_2O$	7.13	cb 19	VI	5	19
8	Azurite	$Cu_3CO_5 + H_2O$	f	c 14	VI	2	13
9	Chrysocolla	$CuSiO_3 + 2(H_2O)$	14.1	dk 13 20			
10	Dioptase	$CuSiO_3 + H_2O$	......	...c 20	III, IV	..	.19 ..
11	Enargite	Cu_2AsS_4					
12	Melanconite	CuO	14.1	j 6			
13	Altacamite	$CuClO_x$	1	bc 21	V		20
14	Blue vitriol	$CuSO_4 + H_2O$	f 21	c 14	VII		1
15	Libethenite	CuP_2O_6	.1.	. 7 21		.	.....
16	Olivenite	$CuAsO_2$	i	16.21			
17	Blue copper	CuS	1	14, 6			
18	Digenite	Cu_9S_8		5			6
19	Cuban	$CuFe_2S_3$			.		
20	Selenid of copper	$CuSe_x$	....	.. a 2.	..	.	......
21	Euchroite	$Cu_2As_3O_5$		20			
22	Aphanesite	$Cu_2As_3O_5$		13.21			
23	Erinite	$Cu_2As_3O_5$	13	20			
24	Liroconite	$Cu_5As_7O_{12}$		13.20	V		
25	Copper mica	$Cu_3AsO_4 + 5(H_2O)$	.4...	... 20....	...	.	......

CHARACTERISTICS

	24f	24b	24c	25	24e	26, 24e		27, 24e			28, 24e			
				Acids		Heat		Tubes			Bor & Phos Beads, Subl.			
									Color		O		R	
Ref. No.	Optic, Electric	Hardness	Specific Gravity	Action Mnrl.	Col'r Sltn.	Change Mnrl.	Color Fl.	Mnrl	H	C	H	C	H	C
6	3.3		6 5	$h^2 s^2 n^2$		11.15								
7	a	3	6.3			14					e 8 f 2			
8		2.8	6.7											
9			8.2								c 8 f 2	8		20
10		3	6	... n .	..8..	..15.22..	. 6							
11		.										. 20.	..	......
12			7											
13			6											
14														
15	. 11.		..	....	..	..15.19..	.							
16		2.8	8								.. ...	...	...	......
17														
18			5.8											
19		3	5.7											
20	...	.	.6.4	.....	...	.....	..							
21								.			..... .	...	..	......
22		1.5	7											
23			4.6			15								
24														
25	...	2.5	6	.....	.	...	.							
26		2.5	5.4					.			......	...	..	......
27		3.5	5.3											
28		2.5	6.2											
29			6.3											
30	. 8	2.5	.6.8	.....	.....	.. 15	.	.						
31											......	...	...	......
32														
0			8 9	$h_1' n^5$	14	6	20							
1	.	2.7	.8.8	$h_1' n^5$	14 .	..6.	20	.			......	...	...	......
2	8	2 7	5.7	n_1		23								
3	8	3	5	n_1		13					11,17,20	8, 14		
4	8	3.8	4.2	n_1		14.13								.
5	..	4	.4.8	n_1 ..	16.20	.. 14	...	b5						
6		3.8	6	n_1		15	.				....	.	..	......
	b	3.8	4	n^2		11.14	20				20	14		
8	ab	4	3.75	n^2		11.14	20				20	14		
9	b	2.5	2.2			24	6	5						
10	.ab.	5..	.3.3	......	...	......	....	..			......	..		.....
11														
12						15								
13	b					15								
14	cb	2.5	2.2											
15	..	4..	3.7	......	......	....	.....	..						
16		3	4.2								.. ...	...	..	......
17			3.8											
18			4.7											
19														
20	. 11.	. .	..	......	.....	....	...	.						
21		3.7	3.4								.. ..	..	...	......
22		2.8	4.2											
23		4.8	4											
24		2.5	2.9											
25	...	2..	.2.5	....	...	......	..	...			......	...	...	......

MINERAL

References for Explanation ...			24a	24c	24d	24f	24e
Ref. No.	Name of Mineral	Formula or Composition of Pure Mineral	Cond. Strctr	Lustre, Color	Cryst. System	Fracture	Color of Streak
26	Copper froth	$Cu_4As_2O_6CaCO_3 + 7(H_2O)$		13.19		2	
27	Condurite			14, 16, 6			
28	Pseudo malachite	$CuOP_2O_5$	1	21			
29	Thrombolite	$CuO_2(P_2O_5)$					
30	Covelline	CuS					
31	Mohawkite	$CuNiCoAz_x$		.	..	..	......
0	Zinc	Zn, At. wt. 65	ac 1.21	a 3 13	II	1	
1	Sphalerite	ZnS	f 1	d 7.17 6	I	2	2,21.17
2	Zincite	ZnO	f 4.1	bc 11.12	V	f 2	9
3	Gahnite	$ZnOAl_2O_3$		21, 6			
4	Willemite	$2(ZnO)SiO_2$	1	7 18		2	
5	Calamine	$2(ZnO)SiO_2 + H_2O$	f 13.1	c 2	V	2	1
6	Smithsonite	$ZnCO_3$	16.1	c 16, 19, 2	IV	2	1
7	Voltzite	$ZnS + ZnO$					
8	Zinc sulphate	$ZnSO_4 + 7(H_2O)$					
9	Zinc bloom	$ZnCO_3 + H_2O$					
0	Aluminium	Al, At. wt. 27	ab 1	a 13.2			......
1	Corundum	Al_2O_3	f 1	bj 3, 1	II	6	
2	Ruby	Al_2O_3		11, 10			
3	Sapphire	Al_2O_3		3.14	III		
4	Amethyst	Al_2O_3		23	III		
5	Topaz	Al_2O_3		c 7, 8.	IV	2.	2...
6	Emery	Al_2O_3	f 1	j 18			
7	Diaspore	$Al_2O_3 + H_2O$	3	c 19, 4, 3.17		6.2	
8	Bauxite	$Al_2O_3 + 3(H_2O)$	10.1	j 13.2, 2			
9	Gibbsite	$Al_2O_3 + 3(H_2O)$	13.17	j 3, 19.2			
10	Spinel	$MgAl_2O_4$		c 11	I.	.2	......
11	Chrysoberyl	$GlAl_2O_4$	f	cd 0, 20	V		1
12	Cryolite	$AlF_3 + 3(NaF)$	1	c 2	VI		
13	Thomsenolite	$CaAlF_2$	1				
14	Kaolin	Al_2SiO_5	1			7	
15	Turquois	$AlPO_4 + H_2O$	..16.1..	.d 13.20..	.		......
16	Wavellite	$AlPO_4 + H_2O$	15	de 7,2			
17	Amblygonite	$AlPO_4LiF$	1	19, 2		2	
18	Lazulite	$AlPO_4MgO + H_2O$	f 1	c 13, 14			
19	Alunite	Al_2SO_6	1	c 10, 3, 2	IV	2	
20	Alum	$K_2Al_2SO_7 12(H_2O)$	..7, 1	. . ..	. I.	.2.	......
21	Dawsonite	$NaAlCO_4$					
22	Pycnite	Al_2FSiO_4	6, 1		IV		
23	Automolite	$AlZnMgO_x$		21, 6			
24	Dysluite	$AlZnMgFeO_x$		3.17			
25	Hercinite	$AlMgFeO_x$		.	...	.	......
26	Halloylite	$Al_2O_3SiO_2 + H_2O$	10, 1	13, 2			
27	Allophane	$Al_2SiO_5 + H_2O$	16, 1	d 20, 17,13		8	. 2
28	Kyanite	Al_2SiO_5	f 7, 3	e 4, 13.2		2	
0	Silver	Ag, At wt. 107 7	ab	ab 2.	I	.	.....
1	Silver, native	Ag	abc 20	a 2	I		2
2	Argentite	Ag_2S	f 1	a 5	I	2	a 5
3	Pyrargyrite	$3(Ag_2S)Sb_2S_3$		ba 12	IV		11
4	Proustite	$3(Ag_2S)As_2S_3$			IV		11
5	Cerargyrite	$AgCl$	c 1	d 4 .	.I.	.8.	. a ..

CHARACTERISTICS

	24f	24b	24c	25	24e	26, 24e		27, 24e			28, 24e			
				Acids		Heat		Tubes			Bor. & Phos. Beads, Subl.			
									Color		O		R	
Ref. No.	Optic, Electric	Hardness	Specific Gravity	Action Mnrl.	Col'r Sltn.	Change Mnrl.	Color Fl.	Mnrl	H	C	H	C	H	C
26											.			
27	10													
28		4.8	4.2											
29														
30		.	..	...	.	...	.....	...		..	....	...	..	......
31														
0			7	h' s' n'		0	2							
1	bd	3.8	4	n^3		7.18	20						e 8	e 2
2	b	4.5	5.5	n		7						8	e 8	e 2
3		7.8	4.2			7								
4		5.3	4			18	14							
5	ab	4.8	3.4	$\cdot h_2$		9.12	20				1	1		
6	bd	5	4.4	n^2		7								
7														
8	C													
9				n^2										
0	..	.	2.6	$h \cdot s_1 \cdot n_1$	..	.....	.. .	...			......	....	...	......
1		9	4			7.18	14							
2		9	4											
3	ab	9	4											
4		9	4											
5	eab	.8	4..	......	..	...7...	10, 7	...	.	.	......	.....	...	......
6														
7		6.5	3.4			11								
8														
9		3 3	2.4											
10	.	8	3.6	......	...	..7...	....	...	.	..	......	.....	...	......
11	abc	8.5	3.5			7								
12		2.4	2.9			1	9							
13														
14														
15		.6	.3	.....	....	...7...	. 20..	...		..	......	.....	...	......
16	b	3.8	2.3	n_1		7	2							
17		6	3											
18		5.5	3											
19	aB	5	2.6	s_1		11, 7								
20	1 B		..	....	...	......	....	..		..	......	.....	...	......
21														
22														
23		7 8	4.2			7, 25								
24		7.8	4.5			7, 26	11				12			
25	...		.	. ...	. .	. .	. ..	.		.	.....	.....	...	......
26		0.5	2	$\cdot n_2$										
27	.	3	1.9	$\cdot n_2$		9	20							
28		6	3.7			7					1			
0	...		10.5	$..n^5$	...	.6 .	.	...			. ..	.....	...	......
1		2.8	10.4	$n_1\ n_3$		15, 21								
2		2.3	7.3	n		9, 15								
3		2.5	5.8	·h s		15, 19								
4	10	2.3	5.5			15, 19								
5	.b.	2.3	.6.3	......	..	.15, 2 .	.. .	. .			.....	.....	...	......

MINERAL

References for Explanation			24a	24e	24d	24f	24e
Ref. No.	Name of Mineral	Formula or Composition of Pure Mineral	Cond Strctr	Lustre, Color	Cryst System	Fracture	Color of Streak
6	Stephanite	$5(Ag_2S)Sb_2S_3$	1	a 6	V		6
7	Stromeyerite	$Ag_2Cu_2S_2$		13.3			
8	Sternbergite	$AgFeS_x$	4	a 17			6
9	Eucairite	$AgCuSe$	5	a 6			
10	Telluric silver	Ag_2Te		13 3.			
11	Silver carbonate	Ag_2CO_3		7.3	..	.	......
12	Chenscoprolite	$AgFeAs$	13	d 8, 19			
13	Antimonial silver	$AgSb$		3.2			
14	Polybasite	$9(AgCu)(SbAs)S_6$			III		
15	Myargyrite	$AgSbS$		...6 .			. 12..
16	Light white silver						
17	Silver bromid	$AgBr$					
18	Silver amalgam	$AgHg$					
19	Silver iodid	AgI					
20	Embolite	$AgClBr$	.....	....	.		......
21	Freieslebenite	$AgSbPbS_x$					
22	Petzite	$AgAuTe$					
23	Schapbachite	$AgBiPbS_x$					
24	Stetefeldite	$AgCuS_xSbO$					
25	Alaskaite	$AgBiCuPbS_x$	.... .	....	..	..	......
0	Nickel	Ni, At. wt. 58.7	. ab	....a 2 ..	..	.	......
1	Millerite	NiS	7	a 8	IV		21, 6
2	Niccolite	$NiAs$	f 1	7.11			16, 10
3	Breithauptite	$NiSb$			III		
4	Genthite	$NiSiO_3+H_2O$	1	20			
5	Garnierite	$NiSiO_3+H_2O$	..1 .	..20...	..		.....
6	Pandlandite	$NiFeS_3$		a 7			
7	White nickel	$NiAs_2$		3.2	I		
8	Nickel glance	$NiAs_2S_4$	1	3.2	I		
9	Amoibite	$NiAsS_x$					
10	Placodine	Ni_xAs_y	..	a 16, 8..	VI	..	......
11	Nickel stibine	$Ni_xSb_yS_z$	1	13.3	I		
12	Green nickel	$NiAs_2O_6$		20			
13	Green nickel hydrate	$NiO+H_2O$	17	c 20			
14	Bismuth nickel	Ni_xBi_y		a 13.3, 2			
15	Melonite	Ni_2Te_3	......	....	...	..	......
0	Tin	Sn, At. wt 118 7.	ab 1, 2	....a 2...	II	..	.....
1	Cassiterite	SnO_2	18, 1	b 18, 6	II		16.4
2	Stannite	SnS	f 1	7.3	I		6
3	Tin pyrites	$SnSCuS$					
0	Cobalt	Co, At. wt. 58.8	.... .	.3.13.2..	..		......
1	Linnacite	Co_3S_4			I		
2	Smaltite	$CoAs$	1	a 3.2	I	4 2	
3	Cobaltite	$CoAsS_x$		a 10.2	I		.
4	Glaucodot	$CoAsS_x$		3.2			
5	Erithrite	$CoAsO_x+H_2O$	16, 11, 4	...ej 11 .	VI	.2.	. 3.11.
6	Danaite	$CoSnFeAs$					
7	Black oxid of cobalt	$CoO2(Mn_2O_3)$	10, 1	6			
8	Cobalt vitriol	$CoSO_4+H_2O$					
9	Ultramarine	$Co_2Al_2P_2O_9$					
0	Antimony	Sb, At. wt. 119 7	..f 21.	..13.2...	...	.1.	......

CHARACTERISTICS

	24f	24b	24c	25	24e	26, 24e		27, 24e			28, 24e			
				Acids		Heat		Tubes			Bor & Phos. Beads, Subl.			
									Color		O		R	
Ref. No.	Optic, Electric	Hardness	Specific Gravity	Action Mnrl.	Col'r Sltn.	Change Mnrl	Color Fl.	Mnrl.	H	C	H	C	H	C
6	8	2.3	6.3	$n\,n_3$		19, 14								
7	8		6.2	$n_1 n_3$		22								
8		1				15					·5			
9	11													
10	.	.	8.5	...		14					. .			.....
11		.				15								
12	10					15								
13			9.5			15, 19								
14			6 3			14, 19								
15	8 .		...	.....	..		.							. ....
16														
17														
18														
19														
20	.		...	.....	..	. ...	. .	. .			.. .	..	.	......
21														
22														
23														
24														
25	..	..	..	....	....	....	... .	...	.	.	......	...	..	......
0	..f.		8 7	.h′ s′.	....	....	....	...			. ....	..	..	......
1		3	5.4											
2	10	5.5	7.5	(hn)		15, 19								
3		5.8	7.5											
4														
5	..	.	...	....	....	....	.....	...	.	.	....	...	.	......
6			4.6											
7														
8		5.5	6.6											
9			6											
10	.	5.3	.8	....	....	....	....	...	.	.	. ....	....	..	......
11		5.3	6.4											
12														
13						20	4							
	a	3.2	3											.
14		4.5	5.1											
15	..	.	..	....	....	....	....	..	.		.. . .	.	.	......
0	.	..	.7.3	$h's\ n_1^5$	....	.2, 11 .	....	..	.		. ....	..	.	......
1	b	6.8	6.8			7, 28								
2		4	4.4											
3														
0	..	.	.8.5	$n'h_1's_1'$	...	......	.. ..	.		.	... ..	..	.	.....
1		5.5	6.3											
2		5.3	6.8	n	10	19						14		
3	.													
4														
5	.ab.	1.7	.2.9	......	..	... ..	....	..			. .	.	...	......
6		.												
7								8						
8														
9														
0	...	...	.6.8	[(hn) $h's_0\,s_1^7$	....	..0 ..	....	...		..	.....	...	...	......

MINERAL

	References for Explanation		24a	24e	24d	24f	24e
Ref. No.	Name of Mineral	Formula or Composition of Pure Mineral	Cond. Strctr.	Lustre, Color	Cryst System	Fracture	Color, Streak
1	Antimony, native..	Sb....	f 3, 1	a 13.2	IV	2	13.2
2	Stibnite.	Sb_2S_3..	6, 7	a 13.4	V	2	
3	Senarmontite. . . .	Sb_2O_3.	6, 18, 1	b 2, 3, 10	V	2	
4	Berthierite.	$Sb_2S_3FeS_2$.					
5	Arsenical antimony	Sb_3As_7. . . .	. 18, 1 .	a 10.2, 3.2	. .		....
6	Red antimony.	$Sb_2O_3Sb_2S_3$. .	6	11		.	16.11
7	Antimonate of lead.	$Sb_2O_5PbO+H_2O$.	2	d 8, 3.20, 6			
0	Bismuth.	Bi, At. wt. 208 4.	f 1	a 10 2 .	I .	2	..
1	Bismuth, native. . .	Bi .. .	f 1	a 10.2	I	2	10.2
2	Bismuthinite. . . .	Bi_2S_3.	1	4	VII		
3	Pucherite. . ..	$BiVO_4$.					
4	Acicular bismuth. .	$BiPbCuS_x$.		5	VII		
5	Tetradymite.	$Bi_2(TeS)_3$.	.4 .	...a 3. .	.		..
6	Bismuthite.	Bi_2CO_5.	1	7, 19	VII		
7	Bismuth-blende. . .	Bi_2SiO_5.	1	8, 18	I		
0	Arsenic...	As, At. wt. 74.8 .					
1	Aresnic, native ...	As.	f 6, 18	a 3.2	IV		3.2
2	Arsenopyrite.	FeS_2FeAs_2.	f 1	a 2	V	2	5, 6
3	Realgar.	AsS.	c 1	d 11	VII		
4	Orpiment.	As_2S_3.	c 4, 1	be 8	V	2	8
5	Arsenolite.	As_2O_3.	14,17,20	2			
0	Manganese.	Mn, At wt. 54.8...	...	... 3 ..			......
1	Pyrolusite.	MnO_2.	9, 7, 1	a 5, 6	V		6
2	Manganite.	$Mn_2O_3+H_2O$....	1	a c 5, 6	V		
3	Braunite.	Mn_2O_3.		a c 5, 6	II		
4	Hausmanite.	Mn_3O_4.	1	a c 5, 6	II		
5	Psilomelane.	$2(MnO_2)+H_2O$. ..	..14, 1	..21, 6. .	...	.	10.18,6
6	Bog manganese (Wad.).	$MnCoPbO_x$.	10,16,1	jk 17, 6			
7	Rhodonite.	$MnSiO_3$.	1	12	VI	2	1
8	Rhodochrosite. . . .	$MnCO_3$.	15, 1	c 16, 10	IV	2	
9	Alabandite.	MnS.		ac 6	I		21
10	Hauerite.	MnS_2.	......	..10.18, 6..	..	.	.....
11	Triplite.	$MnFeP_2O_7$.	1	d 6, 18		2	9, 4
12	Huraulite.	$MnFeP_2O_7+H_2O$.		10.8	VI		
13	Bustamite	$MnCaSiO_4$.					
14	Spiegeleisen.	$MnFe_x$.					
0	Chromium.	Cr, At. wt. 51.97 ..	......	....3....	...	..	......
1	Chromite.	$FeOCr_2O_3$.	1	ca 18, 6	I	10	18
0	Mercury.	Hg, At. wt. 199.5..	1				
1	Mercury, native. . .	Hg.	1	a 13.2			
2	Cinnabar. . .	HgS.	10, 1	bj 11	IV	2	.11
3	Amalgam, native. .	HgAg.		a 2	I		
4	Metacinnabarite. . .						
5	Horn quicksilver .	$HgCl_2$	...c...	..b 3.7 . .	.II.	..	......
6	Iodic mercury. ..	HgI.		10.17			
7	Selenid of mercury.	HgSe.		13.5			
0	Gold.	Au, At. wt. 196.8..	..ab 1..	...a 9....	...	..	......
1	Gold, native.	Au	ab 1	a 9	I		
2	Sylvanite.	$(AuAg)Te_2$.		a 9			
3	Nagyagite.	$Au_2Sb_3S_7Pb_{14}Te_7$. .		a 2			

CHARACTERISTICS

	24f	24b	24c	25	24e	26, 24e		27, 24e			28, 24e			
				Acids		Heat		Tubes			Bor. & Phos. Beads, Subl.			
									Color		O		R	
Ref. No.	Optic, Electric	Hardness	Specific Gravity	Action Mnrl.	Col'r Sltn.	Change Mnrl.	Color Fl.	Mnrl	H	C	H	C	H	C
1		3.3	6.7			16	2	d						
2	8	2	4.6			16, 2								
3		2.8	5.5											
4														
5	...	.3.	.6.2	....	...	.. .	. . .	.			....	...	...	......
6		1.3	4.5											
7		1.3	4.7											
0	...		.9.8	.$'s_1^7$ n.	....	. . .	... .	..			......	..	..	......
1		2.3	9.8			16, 1							e 8	
2		2.3	6.5			1								
3														
4			6.1											
5	..	0.5	.7.1	..... .	.....	.. .	.	.			. .	.	..	......
6		4.3	6.8											
7		4	6											
0								3						
1	.10.	3.5	.5.8	....	...	. 0, 19	13..				..	.	...	......
2	10	6	6			19, 13		6.2			f 2			
3	ab	1 8	3.5											
4	10	1.8	3.5			0, 16	14				f 2			
5	3	1.5	3.7											
0	.	.	8.	......	..	....	... .	..					..	......
1		2.3	4.9								1, 23	13.11		
2		4.3	4.3											
3		6.3	4.8											
4		5.3	4.7											
5	....	5.5	4.2	......	....	.....	....	...			.. ..	.	..	......
6											1, 23	13.11		
		1	3.7											
7		6	3.5											
8		4	3 6	$h^2s^2n^2$							1, 23	13.11		
9		3.8	3.9											
10	....	4.	3.5	...		.. . .	..	...			....	...	...	......
11		5.3	3.6	n_1		22	6				1, 23			
12	a		2.3											
13														
14														
0	....	6..	6.7	..h′s′..	..	.. .	..	...	.	.	....	.....	...	......
1	f	5.5	4.4			7					1, 20			
0			13.6	h_0 $'s_1^7$ n										
1			13.6	$'s_1^7$ n		16								
2	b	2.3	7.5					b 3						
3		2.3	12.5											
4														
5	....	1.5	6.4	......	..	.. ..	..	..	.		.....	......	.....	......
6			.											
7						16								
0	....	..	19.5	..(hn).	....	...		....			.....	......	......	......
1		2.8	19	(hn)										
2		1.7	8											
3														

MINERA

References for Explanation			24a	24e	24d	24f	24e
Ref. No.	Name of Mineral	Formula or Composition of Pure Mineral	Cond. Stretr.	Lustre, Color	Cryst. System	Fracture	Color of Streak
4	Auriferous pyrites.	$Au(FeS_2)S_x$.					
5	Petzite.	$(AuAg)_2Te$.	......	....	...	..	.....
6	Krennerite .	$AuAgTe_x$					
7	Calaverite.	$AuAgTe_y$					
8	Mullerite.	$AuAgPbTe_x$.					
0	Platinum.	Pt At. wt 194.5	.ab 1.	.a 3.2.	...	..	....
1	Platinum, native	Pt	ab	a 13.4	IV		13.2
2	Sperrylite.	PtS_2.					
3	Platinum arsenide	$PtAs_2$.					
4	Platinum iridium.	$PtIr_x$					
0	Iridium	Ir, At. wt. 192 6.	. . .	....	..	..	....
1	Iridium, native.	Ir.					
2	Iridosmine.	IrOs.	18	a 13.3			
0	Palladium.	Pd, At wt 106.3.					
1	Palladium, native.	Pd.	ab 18	a 3.2			
0	Titanium.	Ti, At wt. 47 9	.	a 7 12 .	.I.	..	....
1	Rutile.	TiO_2.	f 1				
2	Octahedrite.	TiO_2		17	II		
3	Brookite.	TiO_2.		7 17	V		
0	Uranium	U, At. wt. 239	f.	7.3.2.	..	..	....
1	Uranite.	U_3O_4		ca 18, 6			6
2	Torbernite.	$UCuPO_xH_2O$.	f 4	e 20	II		19
3	Autunite.	$UCaPO_6+4(H_2O)$	f 4	e 8			7
4	Coracite.	UAl_2O_5	1	d 18			
5	Johannite.	$USO_6+3(H_2O)$.	... .	..20..	...	..	....
0	Thorium.	Th, At. wt. 232.6.					
1	Thorite.	$ThSiO_4+H_2O$.		e 6			
2	Pyrochlore.	$ThTaCeCaO_x$.		c 8, 17	I	2	
3	Monazite.	$ThLaCePO_x$	f	cd 10.17	VI	2	
0	Cerium.	Ce, At. wt 139.8	.. .	.	.		...
1	Monazite.	$CeLaThDiPO_x$	f	cd 10.17	I	2	
2	Flucerine.	CeF_3		8			
3	Parisite.	$Ce_2CO_5+H_2O$.		11, 17	III	2.6	
4	Cerium ochre.	$Ce_2UO_4+H_2O$.		8			
5	Cryptolite.	$Ce_2P_2O_8$.	....	7, 16 .	.III		...
6	Cerite.	$CeSiO_5+H_2O$.		b 11, 17	III		
0	Yttrium.	Y, At. wt. 89	. ..	.	.		....
1	Xenotine.	$Y_nP_2O_{5+n}$		d 10.17	II	2	16
2	Yttrocerite.	$YCeFHCaO_x$.	1	cb 23.14			
3	Gadolinite.	$YGlLaFe(SiO_2)_x$.		cd 19.6	VI		19.
4	Fergusonite.	Y_2TlO_x.		j 16.6	II		
5	Yttrocolombite.	$YTlO_x$.	. ...	..17, 8, 6.			.
6	Euxenite.	$YTlUTiO_x$.	1	16.6	.		10.1
7	Polymignite.	$YFeZrTiO_x$.		ac 6	II	6	18
8	Polycrase.	$YFeZrTiO_x$.					3.1
9	Schorlomite.	$YGlLaFe(SiO_2)_x$		6		5	5
0	Cadmium.	Cd, At wt. 112	ab ..	....	.	.	....
1	Greenokite.	CdS.		b 8	III		

CHARACTERISTICS

Ref. No.	Optic, Electric	Hardness	Specific Gravity	Acids		Heat		Tubes			Bor & Phos. Beads, Subl.			
	24f	24b	24c	25	24e	26, 24e		27, 24e			28, 24e			
				Action Mnrl.	Col'r Sltn.	Change Mnrl.	Color Fl.	Mnrl.	Color		O		R	
									H	C	H	C	H	C
4														
5	....	.	.		..	......	......	..			.. .	...	.	.....
6														
7														
8														
0	....		21 5	(hn).	.	7 ..		.			.	...	...	......
1		4.3	19	(hn)		7								
2														
3														
4														
0	....	..	22.4	.	..	. ...	...				.. .	.	..	......
1														
2	14	6.7	20.5			–								
0											˙8	1	˙8	˙23
1		4.5	12			7, 27					˙8	1	8	˙23
0	....		.	.	.	...					. .	.	.	......
1		6.3	4.3											
2		5.5	3.8											
3		5.8												
0	...	5.5	18.4	h' s' n'	20, 8	.	.				. .	.	.	......
1		5.5	6.4	n		7					4			
2		2.3	3.5			22	20,5.6							
3		2.4	3.3			22	5 6							
4		4.5	4.3											
5	.5.	.	...	.	..	...	.							.....
0														
1			4.6											
2		5	4											
3	b	5	4.9	h'										.
0	..	..	..		...	......	.				......	..	.	.....
1		5	5											
2						7								
3			4.3			7/								
4														
5	.	.	..	.	..	......	..				.... .	.		.....
6														
0	..		..		..	.....	.				.		.	.....
1		4.5	4.6			7								
2	.	4.5	3.4											
3		6.8	4.3											
4						24								
5	.		.		.	..7			.					.....
6		.												
7		6.5	4.8											
8			5 1											
9		7 3	3.8											
0	..		8 7		..	..0, 15.	2 .	.d						...
1	b	3.3	4 9											

MINERAL

References for Explanation ...			24a	24e	24d	24f	24e
Ref. No.	Name of Mineral	Formula or Composition of Pure Mineral	Cond Stretr	Lustre, Color	Cryst System	Fracture	Color of Streak
0	Molybdenum......	Mo, At. wt. 96.. .					
1	Molybdenite.......	MoS_2.	d 4	13.4	III		13.4
2	Wulfenite........	$MoPbO_4$.........	1	d 3.8	II		
0	Vanadium	V, At. wt 51.4....	....	. . ..	..	..	......
1	Vanadinite......	$VPbO_3$.........	15	8, 10.17	III		
2	Vanadate of copper	$CuVO_z$	4, 1	e 8			
0	Tungsten	W, At. wt. 184 ...					
1	Tungstate of lead .	$PbWO_z$.......		d4,11,17,20	II		
2	Tungstate of lime. .	$CaWO_x$..... ..	f	16, 7.2	II	2	
0	Tellurium.. .. .	Te, At wt. 125 ..	......	....	.	..	......
1	Tellurium, native. .	Te....	f	a 13.2	III		
2	Herrerite.........	$TeNi_2O_3CO_2$.....		20			
0	Sulphur..	S, At. wt. 32......					
1	Sulphur, native....	S..............	f 1	d 8	V		8
0	Carbon..........	C, At. wt. 12......	......	....	..	..	.....
1	Diamond.........	C...		b 7, 10, 1, 6	I	2	
2	Graphite.........	$C_{77}FeO$ ...	4, 1		III		6.5
3	Anthracite..	In% $C_{85}(H_2O)_5$ + Ash.	1	c 6			
4	Bituminous coal ..	$C_xH_yO_z$ + ash.....	1	6			
5	Cannel coal.......	" "	1	4.6		6	
6	Jet.............	" "		6			
7	Lignite..........	" "		17, 18			
8	Bitumen.........	" "	..1 1.	d 18 6 .	...	6	......
9	Asphaltum......	" "	1	6		6	
10	Petroleum........	" "	1	21, 6			
11	Amber..........	" " ..	1	d 16.8		6	
12	Retinite.........	" "	c 1	k 7 13, 19			
0	Potassium.......	K, At. wt. 39....	...	. b 2 .	...	..	......
1	Sylvite..........	KCl.		1	I		
2	Orthoclase.......	$KAlSi_3O_8$	18, 1	e2,4,17.11	VI	2	
3	Muscovite.......	$KAlSiO_4$..	e 4, 1	e 1, 2-6	VI	2	
4	Apophillite......	$KCaSiO_3+H_2O$...	4, 1	3.2	II		
5	Saltpeter........	KNO_3.	. 20	...1...	V	..	.....
6	Potash..........	K_2CO_3.........					
0	Sodium..	Na, At. wt. 23...	.....	ab 2 .	...	.	......
1	Halite (rock salt)	NaCl..		3.2	I	2	
2	Borax..	$NaBoO_2+5(H_2O)$		c 1, 2	VI	2	7.4
3	Natron (soda)....	$Na_2CO_3+10(H_2O)$.		1, 2, 3	VI		
4	Trona.	$Na_2CO_3+2(H_2O)$.					
5	Soda-niter	$NaNO_3+$..	....	....	IV	..	......
6	Thenardite.... ..	$Na_2S_2O_7$.					
7	Glauber salt.... .	$Na_2SO_4+10(H_2O)$		7.2	VI		
8	Glauberite.......	$NaCaSO_3$........		7.4			
9	Albite..........	$NaAlSi_3O_8$.. .	f 3,18,1	c 2			
10	Natrolite.	$NaAlSiO_3$	f7,15,11	. c 3.2 .	.	2	....
11	Caustic soda	NaHO					
0	Calcium.........	Ca, At. wt. 40	b	ab 7			
1	Calcite	$CaCO_3$	1	3.2	IV	2	

CHARACTERISTICS

	24f	24b	24c	25	24c	26, 24e		27, 24e			28, 24e			
				Acids		Heat		Tubes			Bor. & Phos. Beads, Subl.			
									Color		O		R	
Ref. No.	Optic, Electric	Hardness	Specific Gravity	Action Mnrl	Col'r Sltn	Change Mnrl.	Color Fl.	Mnrl.	H	C	H	C	H	C
0			8.6								˙8.20	˙8.20	˙12	˙8.20
1	8	1.3	4.6	n h_4 s_4	4	7, 19					c 19.2	f 19.2		
2		3	6.8										8.21	20
0			18.6											
1		2.7	7											
2														
0			17.6											
1		2.8	8											
2		4.3	6			7								
0														
1		2.3	5.9								c 16.8		e 20	
2														
0														
1	ab 8	2	2			0, 16	14							
0														
1	abd	10	3.5											
2		1.5	2			7								
3			1.5			0								
4			1.5			0	10.7							
5						0	10.7							
6														
7														
8	12	2	1											
9														
10														
11	d 14	2.3	1.2			0	10.7							
12	14	2	1.1	2		0								
0			0 9			0	20							
1	5 C		1.8	1		16	23							
2	ab	6	2.5								1			
3	ab	2.3	2.9											
4	ab			˙n_2		9								
5	a 1					11, 16	23							
6	A													
0			0.97											
1	2 C	2	2.2	1		11	8							
2	a 1	2.3	1.7			8								
3	B			1, n^2		10								
4														
5	C			1		29	8							
6														
7	C 23			1		29	8							
8	b 2													
9		6	2.6			5	8							
10	ab	5	2.2	˙n_2		22								
11														
0			1.6			0								
1		3	2.7	$h^2 s^2 n^2$		12, 7								

MINERAL

References for Explanation . . .			24a	24e	24d	24f	24e
Ref. No.	Name of Mineral	Formula or Composition of Pure Mineral	Cond Strctr.	Lustre, Color	Cryst. System	Fracture	Color of Streak
2	Limestone	$CaCO_3$	1	j 0, 3.2		4,6	
3	Aragonite	"		c 0, 3.2	V	2	
4	Miemite	$CaMgCO_4$	7	7 17			
5	Tabular spar	$CaSiO_3$	.	2		.	.....
6	Fluorspar	CaF_2	f 1	0, 2	I		
7	Nitrate of lime	CaN_2O_6					
8	Apatite	$3(Ca_3P_2O_8)CaF_2$	f 1	d 0, 3, 20	III		
9	Gypsum	$CaSO_4+2H_2O$	d 4, 1	0, 4, 8	VI		
10	Anhydrite	$CaSO_4$	.	c, e 0, 3.2	V.	.	.....
11	Sheelite	$CaWO_4$		3.2			
12	Pharmacolite	$CaAs_2O_6+H_2O$		3.2			
13	Diclasite	$CaSiO_3+H_2O$	g 7. 1	7.2			
14	Hydraulic lime	$CaAl_2Si_2O_8$					
15	Perovskite	$CaTiO_x$	.. ..	...4, 6	..I..	..	......
16	Microlite	$CaTaO_x$					
0	Lithium	Li, At. wt 7					
1	Lepidolite		4	22.11			
2	Rubellite						
3	Lithiophilite	$LiMnPO_4$					
0	Barium	Ba, At. wt. 137	.... ..	...ab 2...	.	..	......
1	Heavy spar. Sulphate of baryta	$BaSO_4$	3,1	c 2	V		
2	Witherite	$BaCO_3$	f18,7,1		V		
3	Baryta calcite	$BaCaCO_4$	f 6, 7, 1	e 2	VI		
4	Baryta	BaO					
0	Strontium	Sr, At. wt. 87.6		ab 7			
1	Celestite	$SrSO_4$	7, 6, 1	c 13.3, 2	V	2	
2	Strontianite	$SrCO_3$	f 7, 18	c 0, 2, 19	V	2	
0	Magnesium	Mg, At. wt. 24.3	.3, 18.	. a. .	.		......
1	Brucite	$MgO+H_2O$	d 4	3.2	III		
2	Magnesite	$MgCO_3$	18, 1	cf 3.2, 2	IV	2	
3	Dolomite	$MgCa2(CO_3)$	f 18, 1	c 0, 6, 2	IV	2	
4	Ankerite	$MgCaFeCO_5$		17	IV		
5	Chlorite	$MgAlFeSiO_xH_2O$	4, 18, 1	...7.21	..	..	......
6	Saponite	$MgAlSiO_xH_2O$		7.2			
7	Boracite	$MgBo_2O_4$		c 0, 3.2	I		
8	Epsomite	$MgSO_4$	14, 1	ck 2	V	2	
9	Chondrodite	$MgFeFSi_nO_x$	18	c 0, 17, 6		10	1
10	Talc	$Mg_3Si_4O_{11}+H_2O$	.d 4, 1	.e 3.19, 2.	..	..	......
11	Serpentine	$Mg_3Si_2O_7+2H_2O$	fc 3, 1	d 8.21			
12	Magnesia	MgO		j 7.2			
13	Meerschaum	$MgSiO_x+H_2O$					
14	Chrysolite	$2(MgFe)SiO_4$	f	c 8.20	V	2	
15	Clintonite	$MgAlFeSiO_xH_2O$	.f 4, 1.	ac 10.17.	.	..	..7.4..
16	Carnallite	$MgCl_2KCl+6H_2O$	8	3.2			
17	Kainite	$MgKClSO_4+3H_2O$					
18	Kieserite	$MgSO_4+H_2O$					
19	Nemalite	$MgO+H_2O$					
0	Selenium	Se, At. wt. 79	....	....	...	..	......
1	Selenium, native	Se					
2	Eucarite	$AgCuSe_x$					
3	Crooksite	$CuThSe_x$					

CHARACTERISTICS

Ref No.	24f	24b	24c	25	24e	27, 24e		27, 24e			28, 24e			
	Optic, Electric	Hardness	Specific Gravity	Acids		Heat		Tubes			Bor. & Phos. Beads, Subl.			
				Action Mnrl.	Col'r Sltn	Change Mnrl.	Color Fl.	Mnrl	Color H	Color C	O H	O C	R H	R C
2	i	3	2 5	$h^2 s^2 n^2$		12, 7								
3	ab	3.8	2.9											
4														
5	.										. . .		.	.....
6	ab	4	3.2	s^8		12, 11	0							
7	A													
8		5	3 2	n		12, 5								
9	a	1 8	2.3			11, 24	2							
10	ab	2.8	2.9	..	.	24	2	.			.		..	.....
11														
12		2.3	2 7											
13		4.5	2 3	h_2		5								
14														
15	...	5.5	4	......	.	. .						.	...	......
16														
0														
1														
2						24	2							
3														
0	....		3.95	....	..	.	..				..		.	......
1						6, 11								
		3	4.3											
2		3.5	4.3	$h^2 s_4^2 n^2$		26, 11								
[illegible]		4	3.6											
4														
0			2.5											
1	ab	3.3	4			12,22,11	2, 11							
2	ab	3.8	3.7	$h^2 s^2 n^2$		5	11							
0	.	...	1.7	. . .	. .	.	......	.			......	.	...	......
1		1.5	2.3	h		7, 24								
2		3.5	2.9	h^2										
3	ab	3.8	2.8	$h^2 s^2 n^2$		7								
4		1.5	3.7											
5	..	...	..	....	...	.....	. .				......	.	..	......
6														
7	e	7	2.9			9, 20								
8	B 5-			1		2								
9	b	6.3	3.1			5					7.20			
10	.	1 .	2.8	....	..	.	.				.	. ..	...	......
11		3	2.5			5, 24	16.11	5						
12														
13		2	3	n		24	2	5						
14	ab	6.8	3.4								20			
15	.	..		n..		.7.	.				. 1		...	......
16		2	2.4			20	16							
17														
18				1										
19														
0	...	...	...	....	..	...	.				.....	....	...	......
1														
2														
3														

MINERAL

References for Explanation			24a	24e	24d	24f	24e
Ref. No	Name of Mineral	Formula or Composition of Pure Mineral	Cond Strctr.	Lustre, Color	Cryst System	Fracture	Color of Streak
4	Clausthalite	$PbSe_x$					
5	Lehrbachite	$HgPbSe_x$	..	. .....	.		.....
6	Zorgite	$CuPbSe_x$					
0	Silicon	Si, At wt. 28.4	. .	. ... .	.	.	.....
0	Silica	SiO_2					
1	Quartz	"		0, 6, 1	III		
2	Rock crystal	"		c 1	III	6	
3	Smoky quartz	"		c 6	III	6	
4	Amethyst	"		c 13.23	III		
5	Rose quartz	"	.1.	.c 10	III	.	......
6	Aventurine quartz	"		c 4, 17	III		
7	Cat's eye	"		cd 13, 4			
8	Tiger's-eye	"					
9	Chalcedony	"	17, 1	d 3, 13, 16			
10	Agate	"	.	lm 25	.		.....
11	Carnelian	"	1	11			
12	Onyx	"	1	25, 16, 2			
13	Sardonyx	"	1	25, 16, 2			
14	Prase	"	1	c 19, 20			
15	Chrysoprase	"					....
16	Heliotrope	"		m 11, 21			
17	Jasper	"	1	jlm 18			
18	Flint	"	1	0, 3, 17, 6		6	
19	Hornstone	"	f 1	0, 3, 17, 6		6	
20	Chert	"	.		.		.....
21	Basanite	"		i 6			
22	Lydian stone	"		i 6			
23	Touchstone	"		i 6			
24	Silicified wood	"		1 25			
25	Opal	$3(SiO_2) + H_2O$	11, 16, 2	h 25			
26	Fire opal	" "		8, 11			
27	Harlequin opal	" "					
28	Milk opal	" "		d 3.20, 2			
29	Resin or wax opal	" "					
30	Jasper opal	" "	.				....
31	Wood opal	" "		1 3,17.6			
32	Hyalite	" "	17	7			
33	Geyserite	" "	7, 17, 1	3			
34	Infusorial earth						
35	**Feldspars:**			.	.		......
36	Orthoclase	$KAlSi_3O_8$	1, 3, 18	c 17,11,2,0	VI	2	
37	Albite	$NaAlSi_3O_8$	f1,3,18	c 2,3,10,13	VII		
38	Anorthite	$CaAl_2Si_2O_8$	1		VII		
39	Labradorite	"	1	c 5, 17, 19	VII	2	
40	Hyalophane	$BaAlSiO_x$		.			......
41	Leucite	$KAlSi_3O_8$	f	3	I		
42	Sodalite	$NaAlSi_3O_8$		17, 4, 14	I		
43	Lapis-lazuli	$CaNaAlSi_nO_x$	f	c 14	I		
44	Nephelite	$KNåAlSi_nO_x$	6, 1	c 0, 2, 19	III		
45	Eolite	"	1.	.d .	III.	.2.	......
46	Cancrinite	$KNa(CO_2)_n + AlSi_xO_yH_2O$		d 13			
47	**Pyroxenes**	$CaMgSi_2O_6$	7, 3, 1	c 18, 20	VI		
48	Diopside	"	1	3, 19.2		2	
49	Salite	$CaMgFeSi_nO_x$		d 4.19		2	
50	Diallage	"	. f 4.	...20 ...	..	.	.....

CHARACTERISTICS

	24f	24b	24c	25	24e	26, 24e		27, 24e			28, 24e			
				Acids		Heat		Tubes			Bor. & Phos. Beads, Subl.			
									Color		O		R	
Ref. No.	Optic, Electric	Hardness	Specific Gravity	Action Mnrl.	Col'r Sltn.	Change Mnrl.	Color Fl.	Mnrl.	H	C	H	C	H	C
4														
5	.		..	......	...	.... ..	. .				......	...	...	......
6														
0				...	.	.	.				....	....	...	......
1	ab	7	2.6			7, 30								
2	a	7	2.6			7, 30								
3	b	7	2.6			7, 30								
4		7	2.6			7, 30								
5	. b	7	2.6	......	..	. 7, 30	.				....	...	...	......
6	b	7	2.6			7, 30								
7	b	7	2.6			7, 30								
8		7	2.6			7, 30								
9	b	7	2.6			7, 30								
10		7	2 6	.. .	.	7, 30 .	...				......	....	...	......
11		7	2 6			7, 30								
12		7	2.6			7, 30								
13		7	2.6			7, 30								
14		7	2 6			7, 30								
15		7	2 6	. .		7, 30	.				......	....	..	......
16		7	2.6			7, 30								
17		7	2.6			7, 30								
18		7	2.6			7, 30								
19		7	2.6			7, 30								
20	.	7	2 6	.....	.	7, 30	.				......	...	...	......
21		7	2.6			7, 30								
22		7	2.6			7, 30								
23		7	2.6			7, 30								
24		7	2.6			7, 30								
25		6	2.2			7								
26		6	2.2											
27		6	2.2											
28		6	2.2											
29		6	2.2											
30	.	6	2.2	....		.	.			.	.....	....	...	......
31		6	2											
32	a													
33														
34														
35	...	..	.	...	.	. .	.			.	......	...	...	......
36		6	2.5			5					1			
37	ab	6	2.7			5	8				1			
38		6	2.7											
39	ab	6	2.7	h_1							1			
40	.				.		.			.	. .	. .	..	......
41		5.8	2.5			30, 18	14				1			
42		6	2.3											
43	b	5.5	2.7			22	2	•						
44		5.8	2.5	n_2		5								
45	b .	.	.		...	.	.				....	...	...	......
46														
47		5.5	3.4											
48														
49			3.3											
50	...	.	.3.3	......	...	.....	..	..		..	. ...	....	...	......

MINERAL

References for Explanation			24a	24e	24d	24f	24e
Ref. No.	Name of Mineral	Formula or Composition of Pure Mineral	Cond. Strctr.	Lustre, Color	Cryst. System	Fracture	Color of Streak
51	Cocolite	$CaMgFeSi_nO_x$	f 18	19.2			
52	Augite	$CaMgFeAlSi_nO_x$		6, 21	VI		
53	Hornblende	"	2, 7, 6	c 0, 2-6	VI	2	
54	Enstatite	$MgFeSi_nO_x$					
55	Hyperstene	"	.4	ae 3.6		.	......
56	Bronzite	"	4	ae 19.18,21			
57	Spodumene	$LiAlSi_2O_6$		e 3, 19		2	
58	Hiddenite	"					
59	Wollastonite	$CaSiO_3$.	f 1	c 2	VII	2	
60	**Amphibole**	$CaMgAlFeSi_nO_x$.	..	. .21..	VI	.	......
61	Tremolite	$CaMgSi_nO_x$	20	3, 19, 2	VI		
62	Actinolite	$CaMgAlSi_nO_x$	20				
63	Nephrite	$MgSiO_3$	g 1	c 19, 13, 2			
64	Jadeite	$NaAlSi_nO_x$					
65	Asbestus	$CaMgSi_nO_x$	..8.	.f 19.2	. .	.	......
66	Mountain leather	"	4	3.2			
67	Crocidolite or	"					
68	Blue asbestus	"					
69	**Beryl**	$Gl_3Al_2Si_6O_{18}$	f	c 13.19	III		1
70	Aquamarine	"	.f	.3.19, 13.	.III		......
71	Emerald	$Gl_3Al_2CrSi_6O_{19}$	f	c 20	III	6	1
72	Chrysoberyl	$GlAl_2O_4$		c 20	V		1
73	Euclase	$GlAlFSi_nO_x$	f	c 19	VII	2	
74	Thenacite	Gl_2SiO_4		c 1, 16.10	IV		
75	Herderite	$GlPO_x$		.		..	......
76	Beryllonite	"					
77	**Garnets**		f 3,18,1	c 12	I	2	
78	Grossularite	$Ca_3Al_2Si_3O_{12}$			I		
79	Pyrope	$Mg_3Al_2Si_3O_{12}$	18				
80	Almandite	$Fe_3Al_2Si_3O_{12}$	.. .	..12 ..	.	.	......
81	Spessartite	$Mn_3Al_2Si_3O_{12}$					
82	Andradite	$Ca_3Fe_2Si_3O_{12}$					
83	Uvarovite	$Ca_3Cr_2.Si_3O_{12}$		20			
84	Cinnamon stone	$Ca_2Al_2Si_3O_{12}$		11.17			
85	Hessonite	"					
86	Helvite	$GlMnFeSi_nO_x$		7.17			
87	Danalite	$GlMnFeSi_nO_x$					
88	Eulytite	$BiSi_nO_x$					
89	Zunyite	$AlFSi_nO_x$					
90	**Micas**	..	.. .	.	.	...	......
91	Muscovite	$K_2OAl_2O_3Si_2O_4$	e 4, 1	c 0, 21, 6	VI	2	
92	Biotite	$MgAlFeSi_nO_x$					
93	Lepidomelane	$KAlFeSi_n$		6			
94	Phlogopite						
95	Lepidolite or	....	3, 1	.. 10.23	VI	...	......
96	Lithium mica						
97	Vermiculite	....	3				.
98	Margarite or	$CaAlSi_nO_x$	3	e 3.2	III		
99	Pearl mica	.					
100	Ottrelite	....	.....	......	.	...	......
101	Pinite	$KAlSi_nO_x$		c 4, 19, 16	III		
	Chlorites:						
102	Clinochlore or Clintonite	....	f 4, 1	a,c 11.17	VII		8.4
103	Pennihite						
104	Chrysolite	$Mg_2Fe_2SiO_4$	18	7, 3, 20	V	2	

CHARACTERISTICS

	24f	24b	24c	25	24e	26, 24e		27, 24e			28, 24e			
				Acids		Heat		Tubes			Bor. & Phos Beads, Subl.			
									Color		O		R	
Ref. No.	Optic, Electric	Hardness	Specific Gravity	Action Mnrl.	Col'r Sltn.	Change Mnrl.	Color Fl.	Mnrl.	H	C	H	C	H	C
51	b		3.3			22	1				1			
52			3.4			22					3 20	1	12	1
53		5 5	3.2											
54														
55			2 4											
56			3.2			22	3 20							
57	b	6.8	3.1			9	1							
58														
59		4.5	2 8	n_2		3, 22	1				1			
60			3.1											
61			2.9											
62			3											
63	b	7	3			7								
64														
65														
66														
67														
68														
69	ab	7.8	2 7			22	3							
70		7.8	2.7			22								
71		7.8	2.7			22	3							
72	ab	8.5	3.6			7								
73	ae	7.5	3			9	2							
74	a	8	2.9			7								
75														
76														
77		7	3.9											
78		7.5	3.7											
79														
80														
81														
82														
83														
84														
85														
86														
87														
88														
89														
90														
91	ab	2.3	2.9			7, 22	2							
92														
93														
94														
95														
96														
97						9								
98						9								
99														
100														
101		2.2	2.7			5, 24	2							
102				h s n		7					1			
103														
104	ab					24	7.4,21				20			

MINERAL

References for Explanation			24a	24c	24d	24f	24e
Ref. No.	Name of Mineral	Formula or Composition of Pure Mineral	Cond. Strctr.	Lustre, Color	Cryst. System	Fracture	Color of Streak
105	Boltonite	$MgAlFeSi_nO_x$	18, 1	c 7, 13.4	.	2	......
106	Zircon	$ZrSiO_4$	18	d 0, 17.11	II	6	1
107	Thorite	$ThSiO_4+H_2O$		c 6			
108	Orangite	$ThSiO_4$					
	Scapolites:						
109	Scapolite	$CaAlSi_nO_x+H_2O$	1	e0,13,10,2	II		1
110	Wernerite	$CaNaAlSi_nO_x$	....	......	..	...	......
111	Meionite						
112	Dipyre	$CaNaAlSi_nO_x$					
113	Marialite						
114	Vesuvianite	$CaAlFeSi_nO_x$	18, 1	7.17	II		1
115	Epidote	"	f 6,18,1	c7.20,7.17	VI	2	.1..
116	Allanite	"					
117	Zoisite	"		4.17			
118	Tourmaline	$MgAlFeBSi_nO_x$	f 6, 1	c 25, 18, 6	IV		1
119	Rubellite	$LiAlBSi_nO_x$	f 6, 1	11	IV		1
120	Topaz	$AlFSi_nO_x$	..	c 10, 13, 7	V	6,2	....
121	Danburite	$CaBSi_2O_8$					
122	Iolite	$MgAlFeSi_nO_x$					
123	Keilhauite	$CaTiFeSi_nO_x$	1	16.6		2	3.17
124	Sphene	$CaTiSiO_5$	1	b 0, 3.17, 6	VI	2	
125	Andalusite	Al_2SiO_5	g 1..	c 4, 8.12.	V	2	....
126	Cyanite	Al_2SiO_5	f 7	c 0, 13, 2	VII	2	
127	Sillimanite	"	7, 1	c 4.17	VI	2	
128	Pyrophyllite	$Al_2Si_4O_{11}+H_2O$	...4	.19, 2..	.	..	......
129	Axinite	$CaMgAlFeSi_nO_x$	f	c 21	VII		
130	Staurolite	$MgAlFeSi_nO_x$		c 21, 6	V		
131	Chondrodite	$MgFeFSi_nO_x$	18	c 0, 8, 17		4	
132	Datholite	$CaBSi_nO_x+H_2O$	6, 14	0, 2	VI	..	......
133	Prehnite	$CaAlSi_nO_x+H_2O$	16, 14	c 19, 1	V		
134	Apophyllite	$CaKFSi_nO_x+H_2O$	4, 1	c 0, 8, 2	II	2	
135	Pectolite	$Ca_4Na_2Si_6O_{17}+H_2O$	7	c 0, 2			
	Zeolites:						
136	Zeolite	$CaAlSi_nO_x+H_2O$					
137	Thomsonite	$CaNaAlSi_nO_xH_2O$	f 2, 9, 1	...c 2 ..	V.	...	......
138	Natrolite	$NaAlSi_nO_x+H_2O$	f 11, 15	c 10, 3, 2	V	2	
139	Scolecite	$CaAlSi_nO_x+H_2O$		c			
140	Analcite	$NaAlSi_nO_x+H_2O$		c 1, 2, 3.2	I		
141	Chabazite	$CaKAlSi_nO_xH_2O$		c 11, 7, 2	IV	2	
142	Acadialite	do.	....	....11....	.	...	......
143	Phacolite	do.		1	III		
144	Haydenite	do.			VI		
145	Gmelinite	do.		1	IV		
146	Stilbite	$CaNaAlSi_nO_xH_2O$	6	c 8, 11, 2	II	2	
147	Harmotome	$BaAlSi_nO_x+H_2O$	...f...	. c 3, 8, 2.	.V.	...	......
148	Phillipsite	$CaAlSi_nO_x+H_2O$			V		
149	Heulandite	"	f	c3,10,16,2	VI		
150	Laumontite	"		c 3, 7, 2	V	2	
151	Oligoclase	$CaKNaAlSi_nO_x$					

CHARACTERISTICS

	24f	24b	24c	25	24e	26, 24e		27, 24e			28, 24e			
				Acids		Heat		Tubes			Bor. & Phos. Beads, Subl.			
									Color		O		R	
Ref. No.	Optic, Electric	Hardness	Specific Gravity	Action Mnrl.	Col'r Sltn	Change Mnrl.	Color Fl	Mnrl.	H	C	H	C	H	C
105	ab	5 5	2.8											
106		7.5	4.7			7, 24	1				1			
107			4.6											
108														
109		5.5	2.7			9					1			
110														
111														
112			2.6											
113														
114		6.5	3.4			22	8							
115		6.5	3.4			5								
116														
117						5	-							
118	abe	7.8	3											
119	abe	7.8	3											
120	abe					24	7 10.							
121														
122														
123		6.5	3.7											
124		5.5	3.4			5, 24	8							
125	. b	7.5	3.2			7								
126		6	3.6			7					1			
127		7.3	3.2			7								
128						9								
129	abe	6 8	3.2											
130	b	7 3	3.7											
131	b	6.3	3.2			5					7.20			
132	b	5.3	3	$\cdot n_2$		8	$\cdot$20							
133	b	6.3	2.9	h_4		31	19							
134	b	4.8	2.4	$h_4\ s_4\ \cdot n_2$		9, 22	2							
135														
		4.5	2.7			22								
136														
137	ab	4.7	2.3	$\cdot h_2\ n_2$		5, 9, 20								
138	ab	5	2.2	$\cdot n_2$		22								
139						8								
140		5.3	2.2											
141	ab	4	2.1			9	2							
142						9	2							
143	a					9	2							
144						9	2							
145	a			$\cdot n_2$										
146	ab	3.8	2.1											
147		4.3	2.4											
148				$\cdot n_2$		9								
149		3.8	2.2	h		12, 9								
150	ab	3.8	2.3	$\cdot h_2\ \cdot n_2$		9, 31	2							
151														

31. ORES AND MINERALS.

Useful for the Production of Metals.

AND OF SUBSTANCES EMPLOYED IN VARIOUS INDUSTRIES.

Numbers Refer to Tables 29, 30, 31	Name of Ore. Different Names under the same Number refer to the same Ore	Pure Ore Formula	Pure Ore Per Cent Metal	Metallic or other Product from Ore
	Iron.			
5	Iron sesquioxid Hematite, red ochre Red oxid of iron Specular iron Iron glance	Fe_2O_3	70	Reduced directly (or in the case of hydrates and carbonates often after preliminary roasting) in blast-furnaces with coke, and in some cases with charcoal with the addition of flux, mostly limestone. The product **pig iron,** of various qualities determined by the proportion of carbon, silicon, sulphur, phosphorus, manganese, etc., combined with it, is remelted and, depending on quality, cast into molds to form castings, or subjected to the process of fining and puddling, forming **wrought iron,** to the Bessemer and open-hearth process forming **steel** for rails and beams Charcoal wrought iron, by cementation and subsequent melting in crucible is converted into best **tool steel.**
6	Magnetite, loadstone Magnetic oxid of iron	Fe_3O_4	72 4	
7	Limonite, bog ore Brown hematite Brown ochre Brown oxid of iron	$2Fe_2O_33H_2O$	59.9	
8	Siderite, thomaite Iron carbonate Spathic iron ore Clay iron stone Black band	$FeCO_3$	48.3	
	Lead.			
1	Galena, galenite Lead sulphid Potter's ore	PbS	86.6	Metallic lead is reduced in various ways in blast and reverberatory furnaces or on hearths almost exclusively from galena. The product **pig-lead** when contaminated with other metals, principally silver, which is subsequently extracted, is refined. The pigment, *white lead*, is produced from the pure metal by corrosion and combination with carbonic acid.
6	Cerusite, white lead Lead carbonate	$PbCO_3$	77.5	
7	Anglesite Lead sulphate	$PbSO_4$	67.7	
4	Pyromorphite Lead phosphate	$3Pb_2P_2O_8 + PbCl_2$	76.3	

USEFUL ORES AND MINERALS—(*Continued*).

Ref. No.	Name of Ore or Mineral	Pure Ore: Formula	Pure Ore: Per Cent Metal	Metallic or other Product from Ore
	Copper.			
1	Native copper	Cu	100	*Metallic copper* is mostly
2	Chalcocite			reduced from sulphids by
	Copper glance	Cu_2S	79 8	preliminary roasting and
	Red ruthite			then treatment in rever-
	Vitreous copper			beratory or b l a s t-f u r-
3	Bornite, Erubescite			naces, producing *matte*,
	Sulphid of copper and			from which, by a series of
	iron	Cu_3FeS_3	55 5	roastings and meltings,
	Horse-flesh ore			*blister copper*, is obtained.
	Purple copper			From this, by refining,
	Peacock copper			commercial copper is pro-
	Variegated copper ore			duced.
4	Chalcopyrite	$CuFeS_2$	34 5	Copper ores containing
	Copper pyrite			principally oxids and
	Sulphid of copper			carbonates of copper may
	Fool's gold			be leached with dilute
5	Tetrahedrite	$4(Cu_2S)Sb_2S_3$	36.4	acids The solutions evap-
	Gray copper			orated will deposit cop-
	Sulphid of antimony			per salts of industrial
	and copper			application, as copper
6	Cuprite	Cu_2O	88 8	sulphate or blue vitriol,
	Red copper ore			copper chlorid and hy-
	Cuprous oxid			droxid.
7	Malachite	$Cu_2CO_4H_2O$	57 4	Malachite in selected
	Green carbonate			specimens can be worked
8	Azurite	$Cu_3CO_5H_2O$	55 2	into ornamental articles.
	Blue carbonate			Copper salts, especially
9	Chrysocolla	$CuSiO_3+2H_2O$	36 1	the sulphate, are of ex-
10	Dioptase	$CuSiO_3H_2O$	40 2	tensive industrial appli-
	Emerald copper			cation, in dyeing, in
11	Enargite	Cu_3AsS_4	48.3	calico-printing, and es-
12	Melaconite	CuO	79.86	pecially in electric cop-
	Black oxid of copper			per-plating. Sulphate
	Black copper ore			has been employed for
14	Chalcantite	$CuSO_4$	39.6	the preservation of wood
	Blue vitriol			and animal substances.
	Zinc.			
1	Sphalerite	ZnS	67	*Metallic zinc* is reduced
	Zinc-blende			with coal from its ores,
	Black-jack			mostly subjected to a
	False lead			previous roasting, in re-
	False galena			torts closed at one end,
2	Zincite	ZnO	80.3	in the form of vapor,
	Red oxid of zinc			which condense into
	Red zinc ore			liquid in the iron pipe
3	Gahnite	$ZnOAl_2O_3$	34.8	connected to the open
	Zinc spinel			end of the retort. This
	Automolite			metal, without any fur-
4	Willemite	Zn_2SiO_4	58.5	ther refining, is indus-
	Silicate of zinc			trially employed as an
5	Calamine	$Zn_2SiO_4H_2O$	54 2	alloy with copper, pro-
	Hydrous zinc silicate			ducing brass. It forms
	Electric calamine			almost without exception
6	Zinc carbonate	$ZnCO_3$	59 9	the negative pole of all
	Smithsonite			chemical electric bat-
	Dry-bone			teries. It is employed
				as a preservative against

USEFUL ORES AND MINERALS—(*Continued*).

Ref. No.	Name of Ore or Mineral	Pure Ore: Formula	Pure Ore: Per Cent Metal	Metallic or other Product from Ore
				corrosion, as a coating for sheet iron, which is then known as galvanized iron.
	Aluminium.			
1	Corundum	Al_2O_3		The minerals 1, 2, 3, 4, 11, and 15 when crystallized and of proper color are ground into shape for *prec ous stones* and employed in jewelry.
2	Ruby			
3	Sapphire			
4	Oriental amethyst			
5	Oriental topaz			
6	Emery or corundum			6 in amorphous masses is reduced to powder and fine sand and used as an abrasive and for polishing
8	Bauxite	$Al_2O_33H_2O$	34 6	
9	Gibbsite			
11	Chrysoberyl Cat's-eye Alexandrite	$BeAl_2O_4$		*Metallic aluminium* is reduced from 8, 9, but principally from 12, by various processes, among which reduction in electric furnaces is one of the most successful
12	Cryolite Fluorid of aluminum and sodium	AlF_33NaF	12.8	
14	Kaolin	Al_2SiO_5		The fundamental material for *porc lain* is found in 14.
15	Turquois	$AlPO_4H_2O$		
	Silver.			
1	Native silver	Ag	100	*Native silver* in nature is generally found intermixed in quartz which in addition may contain various other silver compounds The quartz is reduced to a sandy pulp by stamping or crushing between rollers and the native silver is extracted therefrom by amalgamation.
2	Argentite Silver glance Silver sulphid Sulphuret of silver Vitreous silver	Ag_2S	87.1	
3	Pyrargyrite Dark ruby silver Dark red silver	$3(Ag_2S)Sb_2S_3$	59.8	
4	Proustite Light ruby silver Light red silver	$3(Ag_2S)As_2S_3$	65.5	
5	Cerargyrite Horn silver Monochlorid of silver	$AgCl$	75.3	The portion of this ore which is not directly amalgamable is mechanically concentrated and together with other similar ores roasted and then either amalgamated or treated by one of several solution and precipitation processes.
6	Stephanite Brittle silver Sulphuret of silver and antimony	$5(Ag_2S)Sb_2S_3$	68 5	
7	Silver copper glance Sulphuret of silver and copper Stromeyerite	$AgCuS$	53	The amalgam of silver is freed from the mercury by retorting or distillation of the mercury from the silver
8	Sulphid of silver and Iron Sternbergite	$AgFeS$	55	
10	Telluric silver Hessite	$AgTe$	46 3	The precipitated metal from solutions is dried, compressed, melted in crucibles and cast into ingot molds.
13	Antimonial silver Dyscrasite	$AgSb$	47.4	
14	Polybasite Sulphid of silver	$9(AgCu)$ $(AsSb)S_6$	50.6	

USEFUL ORES AND MINERALS—(*Continued*).

Ref. No.	Name of Ore or Mineral	Pure Ore: Formula	Pure Ore: Per Cent Metal	Metallic or other Product from Ore
	Antimony and arsenic			Solutions from pure silver salts are employed in photography, in electroplating and to a limited extent in other arts and industries.
15	Miargyrite Sulphid of silver and antimony	AgSbS	41.5	
17	Bromyrite of silver	AgBr		
20	Embolite, chlorobromid of silver	AgClBr		The metal used for a great variety of useful and ornamental articles is alloyed generally with copper.
19	Iodrite, iodid of silver	AgI	46	
22	Petzite, tellurid of silver and gold	(AgAu)Te		
	Gold.			*Native gold* is mostly found associated with silver in various proportions, in the gravel and sands of old or actual river beds and in quartz veins running generally through granite rocks. In the gravel and sand it is found as dust and occasionally as nuggets of various sizes. In quartz the gold is disseminated through the rock, but in some rare cases may be found in masses sometimes of considerable size. Natural alloys of gold with other metals than silver can only be found as rare specimens of mineralogical interest.
1	Gold, native	Au	100	
	Queensland native gold		92 92	
	Australian, average	–	88	
	California, average		82	
	Paladic gold, average	AuPd	55	
	Parpezite gold, aver	AuRh	64.5	
	Maldonite, gold aver	AuBi	36	
	Amalgam, native	AuHg		
2	Sylvanite	$AuAgTe_2$		
5	Petzite	$(AuAg)_2Te$		
3	Nagyagite	AuAgCuPbTe		
7	Calaverite	AuTe		
8	Müllerite	AuAgPbTe		
4	Auriferous pyrites	FeS_2+Au		
	Platinum.			*Platinum* and *Iridium* are found in similar formations as gold.
1	Platinum, native	Pt	100	
2	Sperylite	$PtAs_2$		Platinum is almost exclusively used for chemical apparatus, and as conducting wires in electric glass lamps.
	Iridium.			
1	Iridium, native	Ir	100	An alloy of platinum-iridium constitutes the material of the international standards of measurements. Iridium has been used for tips of gold pens.
2	Iridosmine	Ir+Os		
	Mercury.			*Native mercury* in small quantities is found disseminated in a porous bituminous substance. The principal ore is cinnabar, from which the mercury is obtained by distillation. The metal
1	Mercury, native quicksilver	Hg	100	
2	Cinnabar Mercury sulphid Natural vermilion	HgS	86.3	
3	Amalgam, native	HgAg	68	

USEFUL ORES AND MINERALS—(*Continued*).

Ref. No.	Name of Ore or Mineral	Pure Ore Formula	Per Cent Metal	Metallic or other Product from Ore
				is extensively used industrially, and for physical instruments. Some chemical compounds are used in medicine and one is in use as an explosive known as fulminate.
	Tin.			
1	Cassiterite Tin-stone Tin dioxid	SnO_2	78.7	*Tin* ore is generally accompanied by iron sulphids, and submitted to a preliminary oxidizing-roasting and then after washing and drying is reduced by heat with coal The metal obtained is refined by repeated liquation Stannates (tin salts) are used as mordants in calico-printing
	Manganese.			
1	Pyrolusite Polianite Black oxid of manganese Manganese dioxid	MnO_2	63	Manganese dioxid is principally employed for the production of chlorin gas. One litre of pure dry gas at normal atmospheric pressure of 760 mm barometric column and 0° C temperature is produced by mixing 3.98 grms of MnO_2 with 25 to 30 cubic centimetres of commercial hydrochloric acid
2	Manganite Manganese hydrate	$Mn_2O_3H_2O$	62 5	
3	Braunite Manganese sesquioxid	Mn_2O_3	69 6	
4	Rhodonite Manganese silicate	$MnSiO_3$	42	
5	Psilomelane	$2(MnO_2)H_2O$		
8	Rhodochrosite Manganese carbonate	$MnCO_3$	47 8	
9	Albandite	MnS	63 2	In the metallurgy of steel a combination of manganese, iron, and carbon in various proportions is employed principally as deoxidizing agent.
10	Hauerite	MnS_2	46.2	
11	Tiplite	MnPO	54	
	Chromium.			
1	Chromite	$FeCr_2O_4$	46.5	50 per cent Cr_2O_3 in an ore is considered as the market standard. The Cr_2O_3 forms a green pigment, chromates and bichromates of potassa are oxidizing agents in dyeing, calico-printing, electric batteries.
10 Pb	Crocoisite Crocoite	$PbCr_2O_4$	27 7	
	Nickel.			
1	Millerite Nickel pyrites Sulphuret of nickel Capillary pyrites	NiS	64.3	Ores of nickel and cobalt occur in nature nearly always associated together
2	Niccolite	NiAs	44	Nickel salts have an

USEFUL ORES AND MINERALS—(*Continued*)

Ref. No.	Name of Ore or Mineral	Pure Ore: Formula	Pure Ore: Per Cent Metal	Metallic or other Product from Ore
	Copper nickel Arsenical nickel			emerald-green color, they have a sweet taste which soon becomes acrid and metallic.
3	Breithauptite Antimonial nickel	NiSb	29	
4	Genthite	$NiSiO_3H_2O$	38.5	Cobalt salts have a peach bloom reddish color The separation of nickel from cobalt is produced in various ways. Sulphids and arcenids of nickel and cobalt may be oxidized by roasting, the oxids dissolved in hydrocloric acid, the solution evaporated to dryness, redissolved in a little water to which is added a concentrated solution of potassium nitrite with an excess of acetic acid Cobalt is thereby precipitated as a brilliant yellow powder Filter and wash with ammonia water; add potash solution to the filtrate, which precipitates all the nickel therein
5	Garnierite	$NiSiO_3$	47	
6	Pentlandite	$NiFeS_3$	28	
	Cobalt.			
1	Linacite Cobalt pyrites Sulphuret of cobalt	Co_3S_4	58	
2	Smaltite Tin-white cobalt	$CoAs_2$	28 2	
3	Cobaltite	CoAsS	35 5	
5	Erythrite Cobalt bloom Arsenate of cobalt	$CoAs_2O_6H_2O$		
7	Black oxid of cobalt Earthy cobalt	$CoOMn_2O_3$	25 3	
8	Cobalt vitriol	$CoSO_46H_2O$	22 1	
	Antimony.			
1	Antimony, native	Sb	100	Sulphids of antimony are generally found crystallized as long gray needles with a metallic lustre A number of salts of antimony are of importance in medicine, like tartrate of antimony and tartrate of antimony and potassium, an emetic The metal is extensively employed as an alloy, principally with lead, to which tin, copper, and zinc may be added in various proportions A band of iron or of zinc plunged in a solution of a salt of antimony, will be covered by a film of the metal
2	Stibnite Antimonite Antimony glance Gray antimony Antimony sulphid	Sb_2S_3	71 4	
3	Senarmontite White antimony Valentinite Antimonious oxid	Sb_2O_3	83.3	
4	Berthierite Haidingerite	$Sb_2S_3FeS_2$	52.6	
5	Kermesite Sulphoxid	$2Sb_2S_3Sb_2O_3$	75 7	
	Bismuth.			
1	Bismuth, native	Bi	100	Bismuth is generally found in the native state Sulphids are comparatively rare The metal alloyed in various proportions with lead and tin forms
2	Bismuthinite Sulphid of bismuth	Bi_2S_3	81	
3	Maldonite Bismuth-gold alloy	Bi_xAu_y		

USEFUL ORES AND MINERALS—(*Continued*).

Ref. No.	Name of Ore or Mineral	Pure Ore: Formula	Pure Ore: Per Cent Metal	Metallic or other Product from Ore
6	Bismuthite Carbonate of bismuth	Bi_2CO_5	82	very fusible alloys the melting-points of which may be lower than the boiling-point of water.
	Uranium.			
1	Uranite Pitch-blende	U_3O_4	91.8	*Pitch-blende* is the ore from which *radium* has been obtained.
2	Tarbernite	$UCuPO_x$		
3	Autunite	$UCaPO_x$		A pigment which colors glass a bright canary yellow, and which is used for painting porcelain, is obtained from these ores.
	Vanadium.			
1	Vanadinite	$VPbO_3$	16.7	Vanadian black, for calico-printing, salts for fixing colors on silk.
2	Vanadate of copper	$CuVO_x$		
	Tellurium.			
1	Tellurium, native	Te	100	Thermoelectric batteries.
2	Herrerite	$TeNiCO_4$		
	Arsenic.			*Arsenious acid*, As_2O_3, is the main commercial product derived from ores of arsenic, which, however, consist mainly of compounds of various metals with arsenic, arsenious acid being obtained as a by-product.
1	Native	As	100	
2	Arsenopyrite Mispickel	$FeAs_2FeS_2$		
3	Realgar	AsS		
4	Orpiment	As_2S_3		
5	Arsenolite White arsenic	As_2O_3		
	Sulphur.			Sulphur is generally purified from native sulphur. The best quality of sulphuric acid is prepared from purified sulphur. Acid from pyrites is generally contaminated with impurities
1	Sulphur, native	S	100	
Fe 1 2, 3	Iron pyrites of all kinds	FeS_8 FeS_2		
	Selenium.			
1	Selenium, native	Se		In selenium the flow of electric current varies with variations of light In the dark selenium is a good insulator and becomes conductor of electricity in sunlight.
2	Eucarite	$AgCuSe_x$		
4	Clausthalite	PbSe		
5	Lehrbachite	$HgPbSe_x$		
6	Zorgite	$CuPbSe_x$		
Hg 7	Selenid of mercury	HgSe		
	Thorium, Cerium.			
Th 1	Thorite	$ThSiO_4H_2O$		*Thoria*, ThO, with 2 per cent of *Ceria*, CeO, are the substances said to produce the glow of the Wellsbach mantles used over Bunsen gas-burners.
Ce 3	Parisite	$Ce_2CO_5H_2O$		
5	Cryptolite	$CePO_4$		
6	Cerite	$CeSiO_5H_2O$		
	Strontium.			
1	Celestine Sulphate of strontia	$SrSO_4$		*Nitrate of strontia*, produces a red color in fireworks
2	Strontianite Carbonate of strontia	$SrCO_3$		
	Barium.			*Nitrate of baryta*, in fire works, produces a yellow color.
1	Heavy spar Sulphate of baryta	$BaSO_4$		*Oxid of barium*, or *Baryta* BaO, is extensively used

USEFUL ORES AND MINERALS—(*Continued*).

Ref. No.	Name of Ore or Mineral	Pure Ore: Formula	Pure Ore: Per Cent Metal	Metallic or other Product from Ore
2	Witherite Carbonate of baryta	$BaCO_3$		in chemistry for the elimination of sulphuric acid from solutions.
	Magnesium.			
1	Brucite	$MgOH_2O$		Besides the metal magnesium, which is generally reduced from 16, various compounds, as magnesia, MgO, form commercial articles. *Epsom salt*, $MgSO_4 7H_2O$, is a medical substance. *Calcined dolomite* is the material used as lining in the *basic steel process*. Talc in its natural state is worked into various ornamental articles, and serpentine is employed as an ornamental architectural stone
2	Magnesite Carbonate of magnesia	$MgCO_3$		
3	Dolomite	$MgCa2(CO_3)$		
8	Epsomite	$MgSO_4$		
10	Talc	$Mg_3Si_4O_{11}H_2O$		
11	Serpentine	$Mg_3Si_2O_7 2(H_2O)$		
16	Carnallite	$MgCl_2KCl + 6H_2O$		
	Calcium.			
1	Calcite Marble	$CaCO_3$		Carbonate of lime crystallized and transparent is known as calcite; crystallized massive from white to black, shaded in a great variety of colors, as marble, is extensively used as an ornamental stone; amorphous, massive in its natural state as building stone, and calcined and mixed with water and sand, as mortar. Gypsum calcined and ground to powder constitutes plaster of Paris, and calcined hydraulic lime is known as cement. From fluor-spar fluor-hydric acid is manufactured.
2	Limestone	$CaCO_3$		
6	Fluor-spar	CaF_2		
9	Gypsum	$CaSO_4 2H_2O$		
14	Hydraulic lime	$CaAl_2Si_2O_8$		
	Sodium.			
1	Halite Rock salt Sodium chlorid	$NaCl$	60 6	Rock salt is the fundamental material from which nearly all other soda compounds can be manufactured; chlorin and hydrochloric acid are obtained from it.
2	Borax Sodium borate	$NaBoO_2 + 5H_2O$		
5	Soda nitre Nitrate of soda	$NaNO_3$		Nitrate of soda is extensively employed for the manufacture of nitric acid.
6	Thenardite	$Na_2S_2O_7$		
7	Glauber salt	$Na_2SO_4 + 10H_2O$		
	Potassium.			
1	Sylvite Chlorid of potassium	KCl		From natural potassium compounds a great number of salts are produced for industrial application. *Saltpetre* is an oxidizing agent and as such an ingredient of gun- and blasting-powder, and is used as raw material for nitric acid.
5	Saltpetre Nitrate of potassium	KNO_3		
6	Potash Carbonate of potassa	K_2CO_3		

32. EXTRACTION OF METALS FROM ORES.

METALLURGICAL ABSTRACT.

Magnesium.

Reduced from carnallite, $MgCl_2KCl+6H_2O$, by electrolytic process and purified by distillation. It is a white lustrous metal, which can be rolled into wire or ribbon. It is not affected by dry air, but oxidizes quickly in the presence of moisture Combining heat of $Mg+O=146{,}100$.

Uses: For powerful light in pyrotechny and in photography; for dehydration of ethers, oils, and alcohols, its hydrate being quite insoluble in these substances; for the reduction of oxids in melted metals, especially in nickel, sometimes in copper, German silver, and even steel. Is the most powerful and reliable reducing agent used in laboratories

In the metallic form introduced in solutions of gold, silver platinum, bismuth, tin, mercury, copper, lead, cadmium thalium, iron, cobalt, and nickel, metallic precipitates are formed. Iron, cobalt, and nickel so precipitated from slightly acid solutions, when washed, dried, and compressed, have great brilliancy, may be completely dissolved in acids and are highly magnetic.

Magnesium introduced into water containing in solution a little common salt, sal ammoniac, or dilute acid, evolves inodorous hydrogen of great purity.

Lithium.

Reduced from anhydrous chlorids by electrolytic process.

Used only in chemical laboratories, it is of no industrial application. It is a silver-white soft metal, which decomposes water at ordinary temperatures.

Beryllium or Glucinium.

Reduced from beryl, $(BeO)_3Al_2O_36(SiO_2)$, or any other bery compound, by an elaborate chemical process.

Of no special application in the arts.

It is a soft, malleable, and tough metal of white lustre, which in the form of powder, wire or thin ribbon burns in the air.

Sodium.

Reduced by heat from anhydrous carbonates mixed with carbon, or by electrolysis, mainly from fused chlorids or hydrates

A soft white metal which alloys readily with lead, tin, and other easily fusible metals, and forms amalgams with mercury

Uses: It has lately been employed in the manufacture of sodium peroxid and of potassium cyanid It is in use for the production of chemically pure hydroxid and is employed in the reduction of a number of oxids, and in the aniline color industry.

Potassium.

Reduced in a similar manner as sodium, but with more difficulty.

It is a white lustrous metal; when freshly cut is softer than sodium. It emits a vapor of green color when heated above 700° C

Uses: In chemical laboratories it is produced as a scientific curiosity. Industrially it has no application. Its chemical actions are similar to those of sodium, only more violent.

Calcium, Strontium, Barium.

These metals are very difficult to obtain even by reduction of chlorin salts by powerful electric currents.

They are all of yellow color and are of no industrial application.

Calcium Carbide, a combination of calcium and carbon, is produced by electrolytic treatment of a mixture of quicklime and charcoal in an electric furnace. It is used for the production of acetylene gas by dripping water on it.

Aluminium.

Grabau Process: Treat a solution of sulphate of alumina with cryolite according to the equation:

$$Al_2(SO_4)_3 + Al_2F_6 6(NaF) = 2(Al_2F_6) + 3(Na_2SO_4).$$

The insoluble aluminium fluorid is filtered, washed, and after being dried and heated to a dull-red heat is charged in a cold vessel lined with pure cryolite The proper proportion of sodium in a lump is put on top of the heated aluminium fluorid and the vessel is quickly covered up.

The reaction, with great evolution of heat, will take place according to the equation:

$$2(Al_2F_6) + 6Na = Al_2 + Al_2F_6 6(NaF).$$

The aluminium melted to a regulus will be found at the bottom of the vessel covered with a slag of cryolite which can be used again for a repetition of the operation. The aluminium so obtained is unusually pure.

Electrolytic and electric heating process: In an iron vessel with a lining of a pure refractory aluminium compound (alumina, cryolite), put as electrolyte a solution of alumina, Al_2O_3, in alkali chlorids and fluorids, or aluminium fluorid Provide the vessel with a carbon anode and a cooled iron or steel cathode The current density is about 2.5 amperes per cm square (16.1 per sq. in) of cathode surface at about 10 volts The solution should be kept at proper strength by the addition of alumina as required The temperature should be kept as low as possible.

Aluminium sulphid produced in accordance with the chemical equation:

$$Al_2O_3 + 3C + 3S = 3CO + Al_2S_3,$$

dissolved in a fused alkaline chlorid, has been proposed as electrolyte.

The color of the metal is bluish white, with a high metallic lustre. The atmosphere at ordinary temperatures has no action on it. Water, dilute organic acids, and nitric acid have almost no action on it. Sulphuric acid dissolves it slowly, but hydrochloric acid and caustic soda attack it energetically.

Uses: For all kinds of utensils in common use. In small quantities as deoxidizing agent in iron, steel, and copper founding. If in cast iron more than required is added it has a tendency to separate carbon in graphitic form.

Cerium, Lanthanum, Didymium.

The cerites in the metallic state are obtained from their fused chlorids by electrolytic process.

Cerium, nearly of the color of iron, is soft and malleable. It combines with copper and iron producing dense alloys. As filings, scrapings, or fine wire, it can be burned, producing a brilliant light.

Lanthanum, of similar color, somewhat hard.

Didymium of a clear gray color is harder and less malleable than cerium.

Uses: Of no special industrial use. They might be employed to alloy with other metals and to reduce their oxids, if the raw material should be found to be more abundant.

Copper.

The ores most commonly used for the extraction of copper are the copper pyrites, $Cu_2S \cdot Fe_2S_3$, and other sulphids of copper.

The Welsh or Roasting Process consists in a succession of roasting and calcining operations, and of melting and casting, thereby obtaining a gradual concentration of copper by the oxidation of most of the foreign matter and by converting a portion into slag. By this succession of operations blister copper, with only a small percentage of impurities, is obtained This is subjected to final refining by special treatment in a furnace, or by electrolysis in an acid sulphate of copper solution.

The German or Swedish Reduction Process consists in (1) roasting the ore; (2) melting, obtaining a matte with 30 to 40 per cent of copper, called coarse metal; (3) roasting the coarse metal; (4) melting, obtaining a matte with 60 to 70 per cent copper, called fine metal; (5) roasting the fine metal; (6) melting, obtaining after casting black copper.

Leaching Copper Ores and Furnace Products.—Oxids and carbonates are treated directly with dilute sulphuric acid or hydrochloric acid, or with chlorid solutions, other compounds are oxidized by weathering, or are subjected to a chloridizing roast, or treated with oxidizing or chloridizing agents and dissolved in water or dilute acids

From solutions of this kind sulphates or hydroxids are obtained by evaporation, or cement copper by precipitation with metallic iron, or refined copper is obtained from such solutions by electrolysis.

Bessemerizing Copper Matte.—This operation is performed in a converter with acid lining, similar to the one employed for steel. The tuyeres, however, are placed at the side and not in the bottom. The matte treated should contain as an average 50 to 55 per cent copper, the extremes being 45 to 60 per cent. The blast pressure should be about 11 pounds per square inch. The result is blister copper of about 99 per cent pure metal.

Uses: The great variety, extensive and numerous employments in the arts and industries of this metal is generally so well known that no special mention of them need be made here.

Silver.

Silver ores, after being pulverized, are generally treated by amalgamation. Metallic silver is easily dissolved in mercury; silver salts and silver sulphids are decomposed by the same metal. Other ores are subjected to a chloridizing roast, and with the addition of a reducing agent the silver is separated by amalgamation with mercury and subsequent distillation of the latter.

Silver is separated from lead, 1st, by a process of concentration (Patinson's process), and subsequent cupellation; 2d, by concentration in molten and crystallizing zinc (Parker process); 3d, by concentration in zinc with the addition of a small quantity of aluminium (Roesler and Edelmann). In all these cases the silver is isolated by the distillation of the zinc.

Zier-Vogel Process.—Silver is separated from argentiferous copper matte by roasting so as to form copper sulphate, crushing, and re-roasting so as to form by double decomposition silver sulphate, dissolving in hot water and acid copper-sulphate solution, finally precipitating the silver from this solution by metallic copper.

Augustin Process.—Silver ore is treated by a chloridizing roast, the silver chlorid formed is dissolved in a concentrated solution of sodium chlorid; from this solution the silver is precipitated by metallic copper.

Patera Process.—The silver chlorid is dissolved by a sodium-thiosulphate (hyposulphite of soda) solution, and is converted into silver sulphid by the addition of sodium sulphid.

Kiss Process.—The solvent for the silver chlorid is a calcium thiosulphate solution and silver sulphid is obtained by adding a calcium sulphite solution.

Russell Process.—The roasted and chloridized ore-pulp is leached with water and then lixiviated with a 1¼ to 1½ per cent solution of sodium hyposulphite (sodium thiosulphate), dissolving the silver chlorid. Lead contained in the solution is precipitated as carbonate of lead by the addition of pure carbonate of soda. From the decanted solution, silver sul-

phid is obtained by the addition of sodium sulphid. Any residue of silver in the ore differently combined than chlorid is dissolved in a solution of a double salt of sodium sulphate and copper sulphate. From this solution the silver and copper are precipitated as silver sulphid and copper sulphid by the addition of sodium sulphid.

The filtered precipitate of the two operations before completely dry is treated with sulphuric acid with the addition of sodium nitrate, producing quite a violent reaction. Gold or silver chlorid will not dissolve. The silver is precipitated from the solution by metallic copper.

Wet Assay of Silver.

Dissolve in nitric acid, evaporate to dryness in presence of sulphuric acid Dissolve in boiling water and immerse immediately a plate of cadmium in the solution. The compact black-gray precipitated mass should then be boiled in the acid water until hydrogen ceases to be evolved. Wash free of sulphuric acid, decant, dry, and calcine, giving thereby the silver its metallic lustre, and weigh.

Electrolytic Silver Refining.

Moebius Process.—The anodes are made of silver plate of 95 to 98 per cent pure silver, with various proportions of other metals such as copper, lead, zinc, bismuth, etc They are surrounded by tight canvass stretched over wooden frames. The cathodes are made of a thin silver plate, on each side of which strips of wood projecting from a moving frame are kept in motion, so as to detach constantly strips of silver crystals which form on the cathode. These fall to the bottom on a filtering-cloth stretched below the cathodes in the wooden box containing the electrolyte The electrolyte consists of a weak acidulated solution of silver nitrate contained in a wooden tank of rectangular form, strongly assembled and made water-tight and acid-proof by a coating.

Borcher's Process.—The anode consists of granulated alloys containing about 60 per cent pure silver. The cathode of sheet silver is suspended in a cell with perforated double walls on both sides, with close-filtering material inserted between the double walls on each side. The bottom of the rectangular

tank containing the electrolyte is beveled and the granulated metal of the anode is filled in between the end walls of the tank and the double walls of the cell containing the cathode. The conductors of the anodes are rods of the same composition as the granulated metal The electrolyte of dilute nitric acid or of a solution of nitrates, preferably of copper nitrate, is introduced in the cell and flows through an opening in the bottom of the cell to the beveled bottom of the tank, and then up through the granulated alloy to the top, where it is discharged through a pipe and collected for further treatment, for the separation of the dissolved metals and impurities carried away.

Uses of Silver.—Pure silver is almost exclusively used for chemical compounds employed in photography, electroplating, etc In the arts it is generally employed alloyed with various percentages of copper. In this condition it is formed into a variety of objects of art and household articles.

Gold.

Placer Mining.—Gold in the metallic state is obtained from disintegrated rock in the form of sand and gravel, by washing. It is generally obtained in this manner in fine particles known as dust. It has occasionally been found in lumps of various sizes known under the name of nuggets.

Amalgamating Process.—When the gold is adherent to rock the gold-bearing rock is reduced to a sandy powder (pulp), mixed with mercury, and washed by water over amalgamated copper plates (plates coated with mercury), where the already formed gold amalgam and the fine metallic particles of gold coming in contact with the coating of the plates are retained. The sand is then washed over rifles and blankets and treated in concentrating machines separating the light from the heavy parts, retaining the latter for further treatment, consisting mainly in roasting and reamalgamating.

Chlorination. Platner's Process.—In a charge of gold-bearing pulp, contained in a revolving iron drum lined with lead, a stream of chlorin gas is conducted, producing chlorid of gold, which is soluble in water

Thies Process.—For each ton of ore in the revolving drum, 130 gallons of water, 30 pounds chlorid of lime, and 36 pounds

concentrated sulphuric acid are added, and the drum revolved for some time. A solution of chlorid of gold is thus obtained

The silver remains as an insoluble chlorid, which can afterward be separated by dissolution in sodium hyposulphite solution or in brine.

Cyanid of Potassium or McArthur and Forest Process.—The pulped ore is leached with a solution of 0 2 to 0.8 per cent of potassium cyanid, KCy, and then with water. The gold is obtained from this solution by precipitation with zinc or aluminium, or by electrolysis.

The cyanogen in the cyanid solution should not exceed eight parts to one thousand parts of water.

Separation of Gold from other Metals.

Cupellation.—Lead is separated from gold or from gold and silver by conversion into litharge of the lead, by means of heat and exposure to the oxidizing action of air.

Roesler's Process.—Copper, and in part silver, is separated from gold by fusing with sulphur or with antimony sulphid, obtaining copper or silver sulphid.

Miller's Process.- Silver is separated from gold by fusing in a refractory crucible, covering with borax, and passing a stream of chlorin through the molten metal, converting the silver into silver chlorid.

Solution by Acids, Quartation.—Silver is separated from gold by solution in nitric acid, producing nitrate of silver

A granulated alloy of gold and silver heated with strong. sulphuric acid produces sulphate of silver. The brown residue of gold is washed, dissolved in aqua regia, and precipitated with ferrous salt. The precipitate, after being filtered and washed, is melted with fluxes and cast into gold bars.

The silver in the sulphate is precipitated by scrap-iron, filtered, washed, dried, fused and cast into bars.

Electrolytic Treatment.

Siemens-Halske Process.—Gold-bearing pulps or amalgamator tailings are treated with a weak solution of cyanid of potassium. The solution containing most of the gold is collected in an iron electrolyte tank. The anodes are made of sheet-iron plates and the cathodes of lead plates of same dimension, sup-

ported by wooden frames. The electrodes are placed in the rectangular tank a little over 1 inch apart, and are electrically connected to longitudinal copper rods in electric connection with a dynamo of proper construction. The current density should be about 60 amperes per sq. metre (5.6 amperes per sq. foot) at an electromotive force of 4 volts. The gold collects on the lead plates, which are from time to time withdrawn, and the gold is then separated by cupellation. The solution should contain only from 0 05 to 0.08 per cent of cyanid of potassium, and in some cases only 0 01 per cent has been employed.

Uses.—Pure gold is used for chemical preparations, for gold-plating, etc. For coinage 90 per cent gold is generally alloyed with 10 per cent copper. English gold coins contain 91 6 per cent of pure gold For jewelry and other goldsmith's work, gold is alloyed with various other metals, mostly silver and copper, in variable proportions.

Zinc.

Zinc ores are generally submitted to mechanical operations for concentration and are then roasted. The roasted ore is intimately mixed with coal and the zinc is reduced in retorts of refractory material at a red heat, where it is converted into vapors which are condensed into metal in iron pipes or hoods connected to the open ends of the retorts, the molten zinc being collected in pots placed below these pipes. From these pots it is ladled into molds for the production of the commercial ingots or cakes.

Belgian Process.—This is the process most commonly employed industrially. The retorts consist of cylindrical pipes of refractory material closed at one end, of a length and diameter convenient for charging and cleaning them, and of sufficient strength to resist distortion as much as possible while in use.

A considerable number of these retorts are set horizontally in a properly constructed furnace in parallel horizontal and vertical rows. The open ends of the retorts, which are placed somewhat lower than the closed ends, are covered by a sheet-iron hood to which are connected short conical sheet-iron pipes discharging the molten zinc downward.

Uses.—Zinc is extensively used in metallurgical works for desilverization of lead, as a reducing agent in chemistry, as electrodes in galvanic batteries, as the main compound with copper in alloys for brass and, with copper and tin, for substitutes for bronzes. It is rolled into sheets for a multiplicity of useful purposes, and is applied as a coating of sheet iron for galvanized iron, etc.

Cadmium.

Cadmium is obtained mostly as a by-product in the metallurgy of zinc, as its ores generally accompany those of zinc A more or less brown oxid of cadmium accumulates in the iron condenser of zinc retorts, from which cadmium, more or less mixed with zinc, can be distilled and, after purification, may be cast into rods.

Uses.—The metal is mainly used for fusible alloys. Its haloid salts are used in photography and the sulphid is employed as a pigment.

Mercury.

Sulphid of mercury, or cinnabar, is the ore from which most generally mercury is obtained by distillation. It is purified partly by filtration and partly by redistillation.

When pure it can be separated into bright perfect little globules which instantly unite when brought together. When contaminated with lead, zinc, or bismuth the globules tail and leave a streak when rolled on a glass plate.

For purification: 1. Pour the mercury in a tray with flat bottom in a thin layer and cover with nitric acid, leaving it exposed for a day or two with occasional stirring until the mercury no longer tails. 2. Cover the mercury in the tray with protonitrate of mercury and treat as above. 3. Shake the mercury in a bottle with air and powdered sugar, renewing the air from time to time. Filter through a paper cone with a hole in the apex pricked with a fine needle.

Uses.—This metal, being liquid at ordinary temperatures, is extensively used for scientific apparatus in physical and chemical laboratories; in metallurgy for amalgamation of gold and silver from its ores; in the preparation of a number of chemical compounds for medical and industrial purposes, for explosives, and for pigments.

Tin.

The almost exclusive ore of this metal is cassiterite, SnO_2. After being separated by mechanical means from foreign matter, it is converted to the metallic state by reduction with coal under heat, the foreign matter yet present being liquefied by proper fluxes The crude metal obtained is refined by liquation.

Electrolytic Process.—Tin scrap has been treated, in a bath of a solution of 12 to 15 per cent of sodium chlorid mixed with about 5 per cent of caustic soda, by a current of 1 5 to 2 volts and 150 amperes per square metre, resulting in spongy tin, iron, and a little preparing salt (mordant for calico printing and dyeing) The scrap in a basket, which may be of iron, serves as anode and a sheet of iron is used as cathode

Uses.—Tin is largely used as a coating for other metals (tin-plate, tinned wire, etc.), as an alloy with copper (bronze), with lead (tinners, and plumbers' solder), and with some other metals, as tinfoil, for all kinds of purposes. Chemical compounds of tin are used in calico printing and dyeing as mordants, and as pigments for paint.

Lead.

Only galena, PbS, and cerusite, $PbCO_3$, are generally used as lead ores, but lead is extracted in many cases from waste products of other metallurgical operations.

Reaction Process.—When galena, PbS, and cerusite, $PbCO_3$, are mixed in proper proportions and subjected to heat, the carbon dioxid, CO_2, is driven off in the first stage of the operation, and the sulphid reacts on the oxid of lead,

$$2PbO+PbS=3Pb+SO_2,$$

producing metallic lead and sulphur dioxid.

In treating galena exclusively a portion is roasted to oxid and then mixed with the proper quantity of raw ore, when the same reaction will take place.

The first portion of galena may be roasted to a mixture of sulphate of lead, $PbSO_4$, and oxid of lead, PbO, and the proper proportion of raw ore added. The chemical reactions will then be as follows:

Roasting to oxid and sulphate:

$$2PbS+7O=PbO+PbSO_4+SO_2.$$

Reducing from oxid to lead:

$$2PbO + PbS = 3Pb + SO_2.$$

Reducing from sulphate to lead:

$$PbSO_4 + PbS = 2Pb + 2SO_2.$$

Corinthian Process.—Small charges are treated at the lowest temperature possible in small furnaces. Part of the charge is roasted to sulphate and mixed with the part not roasted. Whatever has not been reduced to metal is treated with charcoal and by proper manipulation mostly reduced to metallic lead. The residue, containing from 3 to 9 per cent of lead, is concentrated to 50 to 60 per cent and remelted.

English Process.—Large charges of ore are treated at high temperatures in large furnaces. The roasted part is immediately reduced by the sulphid. The impurities are from time to time converted into easily fusible slags which are removed to be smelted in special furnaces, as they generally are yet rich in lead.

Tarnowitz Process.—Large charges are roasted at low temperatures in large furnaces and treated substantially as in the Corinthian process. The residual containing considerable lead is remelted in special furnaces.

Ore Hearth Process.—The ore mixed with fuel is treated on a hearth, the roasted portion is reduced by the unaltered ore and by the carbon of the fuel.

Roasting and Reduction Process.—Sulphid ores are roasted and as completely oxidized as possible and, with oxidized products of previous operations, reduced by carbon in low blast-furnaces (20 to 26 feet high). Sulphates formed in roasting should be decomposed by silica in accordance with the reaction expressed by the formula

$$PbSO_4 + SiO_2 = PbSiO_3 + SO_2 + O.$$

The silicate of lead in turn is decomposed by lime:

$$PbSiO_3 + CaO = CaSiO_3 + PbO.$$

When copper is present part of the lead sulphid should be employed for the formation of copper sulphid:

$$PbS + 2Cu = Cu_2S + Pb$$

... other metallurgical operations are crushed and treated with hydro-

Zinc is converted by roasting into zinc sulphate and removed from the roasted ore by leaching. Lead ores containing silver and zinc in various proportions are: 1, roasted at a low temperature, converting zinc sulphid into zinc sulphate; 2, leached with water and sulphuric acid for dissolution of the zinc sulphate and treated with sulphur dioxid and air for conversion any free zinc oxid into sulphate; 3, the leached ore is smelted, producing lead combined with silver; 4, the lead is desilverized, resulting in the production of lead and silver; 5, from the sulphate of zinc metallic zinc is recovered.

Precipitation Process.—Part of a charge of lead sulphid is reduced into metallic lead by iron and part into a lead matte or double sulphid of lead and iron as shown by the following chemical equations:

$$PbS + Fe = FeS + Pb,$$

$$PbS + nFeS = PbS\ nFeS.$$

The matte is roasted and oxidized, resulting in lead and iron oxids mainly, which are added to a new furnace charge. The iron is charged in the furnace in the form of oxidized ores, such as roasted pyrites, red and brown hematites, and reduced in the operation of smelting by the carbon present.

Lead-refining.—If lead is melted at a low heat any copper present will rise to the surface and is removed by skimming.

Iron, nickel, cobalt, and zinc are oxidized by passing superheated steam through the molten lead at a red heat. Antimony and arsenic may be separated by melting and oxidizing; antimonate and arsenate of lead are formed on the surface and are removed by skimming Silver and gold are concentrated by Pattison's or Parker's process and are separated from the lead by cupellation. From desilverized lead antimony can be removed by the steam-blast.

Bismuth is separated by repeated smelting and oxidation, until oxids are obtained containing up to 30 per cent of bismuth, which are then treated in the wet way.

Electrolytic Refining of Lead.

Keith Process.—The electrolyte is composed of a solution of lead acetate or of lead chlorid. From the impure or work [illegible] the anodes are cast into plates,

which are enclosed into bags of coarse muslin. The cathodes are made of thin metal plates The deposit obtained is in crystalline form and falls to the bottom of the vessel, which may be made of plate iron or of wood.

Tomassi Process.—The electrolyte is a solution of a double acetate of lead and of potassium or of sodium. The anodes are cast from crude argentiferous lead; the cathodes are in the form of large disks of copper or of aluminium bronze and are about half immersed in the electrolyte, in which they slowly revolve, each being placed between two anodes. The lead crystals formed are detached by scrapers. When in sufficient quantity they are collected, drained, washed, dried, and fused with a little charcoal.

Uses.—Lead is manufactured into pipes, sheets, bullets, shot, and is used in numerous alloys—with tin in plumbers' and tinners' solders, with antimony in type metal, etc. It is employed as a solvent for gold and silver. Converted into carbonate of lead it constitutes a pigment of white color extensively used in painting. In a spongy condition, produced by electrolysis, it is used as electrodes for storage-batteries. Heated and oxidized it is converted into red lead and litharge. Chemical and metallurgical vessels are lined with lead for various purposes.

Bismuth.

Reduction Process.—Oxid and sulphid ores and compounds are mixed with soda, limestone, slags from previous operations, and charcoal, and are smelted in a crucible.

Basic bismuth salts as oxychlorid should be thoroughly mixed with caustic lime or stirred in milk of lime and dried. There should be soda enough to produce a very fluid slag The bismuth obtained is generally contaminated with lead, arsenic, antimony, and often with other metals, such as copper.

Precipitation Process.—Sulphids and arsenical ores are fused fluxed by soda, limestone, and slags, with the addition of scrap iron. Copper combines with sulphur and with iron sulphid into a matte. Cobalt and nickel combine with arsenic to form a speiss. The bismuth obtained retains some lead and antimony and has to be refined.

Wet Process.—Products containing bismuth from other metallurgical operations are crushed and treated with hydro-

chloric acid of moderate strength. The bismuth chlorid remains in solution, the lead being insoluble. By mixing the solution with a great volume of hot water basic bismuth chlorid is precipitated The precipitate after filtering is washed and the operation repeated; the final precipitate, after thorough washing, is mixed with milk of lime, and after drying, melted in a crucible with the fluxes indicated in the reduction process.

Refining.—The refining method is dependent on the preponderance of any of the substances, forming the impurities of bismuth as lead, antimony, arsenic, etc.

If more than a fraction of 1 per cent of lead is present the crude metal is added to a melted mixture of potassium and sodium chlorids and some caustic soda in an iron pot. A quantity of bismuth oxychlorid, corresponding to the lead to be removed, is then stirred in and the stirring continued from 2 to 3 hours. When a test portion solidifies with a crystalline foliated structure, the fire is withdrawn, an iron hook is inserted in the melted mass, which is left to cool and is withdrawn by means of the hook. The slag is dissolved and the lump of bismuth is then broken up.

For the elimination of arsenic or antimony the bismuth is fused with soda and nitre If a large proportion of antimony should be present, then sodium sulphid is melted with the bismuth. The temperature should be kept as low as possible and the charge should be thoroughly stirred.

Uses.—For easily fusible alloys and for hard alloys (bismuth bronze); for pharmaceutical and cosmetic preparations as subnitrate and oxychlorid of bismuth.

Antimony.

This metalloid, of a white metallic lustre, is crystalline and brittle. It is obtained from sulphid ores, stibnite, Sb_2S_3, which are smelted direct, when from 50 to 90 per cent of pure ore composes the charge. Poorer ores are concentrated by liquation. The sulphid, with the addition of a mixture of carbon and sodium sulphate to which scrap iron is added, is melted in a crucible or in a reverberatory furnace.

Roasting and Reduction Process.—Sulphid ores are submitted to an oxidizing roasting, either at a low temperature with scant air-supply, producing a volatile antimonious oxid, Sb_2O_3, or at a higher temperature with excess of air, obtaining

an antimonious antimonate, SbO_2. The roasted ore, with the addition of sodium sulphate, of slags from previous operations and if necessary of soda, is smelted in a furnace or crucible.

Electrolytic Reduction.

Borcher Process.—Powdered antimony sulphid ore is gradually sprinkled in a hot solution of sodium sulphid heated to boiling and agitated by steam, in a conical iron vessel, with admission of air from time to time. After the solution has attained a concentration to 9° or 10° Baumé, hot, 12° B., cold, it is left to settle and the clear solution is siphoned into a tank and 3 per cent sodium chlorid added. The solution is then transferred into an iron electrolytic tank having iron plates as cathodes electrically connected with the tank and lead plates as anodes. With a concentrated solution the current strength may be 100 to 150 amperes per sq. metre (0.061 to 0.1 per sq. inch), decreasing gradually to 40 or 45 amperes as the solution becomes weaker, the electromotive force being a little less than 2 volts. The antimony accumulates at the bottom of the tank, which acts as cathode.

Refining.—Crude antimony from any of the processes mentioned may contain some impurities It is melted in a crucible or reverberatory furnace, first with liquated antimony sulphid, removing iron and copper as sulphids; then with potash or soda, with the addition of a small proportion of oxid or of sulphid of antimony

Uses.—Antimony alloyed with lead produces type metal with tin and a small quantity of copper, anti-friction metal It is used in thermoelectric batteries. Some of its oxids are used as pigments.

Chromium.

This metal is of a bright gray metallic lustre, is very hard and crystalline

Reduction Process.—Chromite, $FeOCr_2O_3$, is calcined with potash or soda in the presence of air. The chromate of potash or of soda and the iron oxid produced are roasted with sulphur so as to produce sulphates which are dissolved The insoluble chromium oxid is washed and dried, and mixed with carbon is submitted to a white heat in a plumbago crucible. A gray

metallic powder is obtained which is a combination of chromium and carbon.

Refining; Moissan Process.—Chromic oxid is reduced with carbon in an electric furnace, the hearth of which is lined with a calcium chromite prepared by heating together lime and chromic oxid.

Uses.—Ferrochrome is employed in the iron industry and in the manufacture of chrome steel. Chrome salts are employed in chemistry and some oxids are used as pigments for painting.

Molybdenum.

This metal has a white metallic lustre and is very hard. The minerals constituting the ores of this metal are molybdenite, the sulphid MoS_2, and wulfenite the molybdate of lead, $PbMoO_4$. The metal has been obtained by heating the trioxid MoO_3 in a current of hydrogen, or by reduction with electrically heated carbon.

Uses.—The metal is so far of no special application, and has only been used experimentally in steel-making.

Tungsten.

This metal is of a grayish-white lustre and very hard. It is obtained alloyed with iron from wolfram, $FeWO_4$, by melting with carbon, glass, and scrap-iron, in a plumbago crucible, at a very high heat. The pure metal is only obtained from trioxid, WO_3, which is produced by calcining the ore with soda, dissolving this product in water, separating the insoluble matter by filtration, crystallizing and recrystallizing the tungstate of soda, Na_2WO_4, obtained for purification, and decomposing by treating with hot hydrochloric acid, producing a heavy yellow precipitate of tungsten trioxid. After being washed and dried the oxid, mixed with charcoal and rosin, is reduced in a clay crucible in a furnace. A gray metallic powder will result, which may be fused in an electric furnace.

Uses.—Tungsten alloys are used in the steel industry. Muslin can be rendered uninflammable by tungstate of soda solution.

Uranium.

This metal is of a white metallic lustre and hard. It is obtained principally from uranite, pitch-blende, a urano-uranic oxid, $U_3O_8 = UO_2 \cdot 2UO_3$, and has been reduced by electrically heated carbon.

Uses.—Some oxids are used as pigments for staining glass.

Manganese.

This metal is of a reddish-white metallic lustre, very hard and brittle. The ores from which the metal, or, more generally, manganese alloys are extracted are pyrolusite, the binoxid MnO_2; braunite, the oxid Mn_2O_3; hausmanite, the mangano-manganic oxid, Mn_3O_4; manganite, the hydroxid, $MnHO_2$; hauerite, the sulphid MnS_2; dialogite, or rhodochrosite, the carbonate $MnCO_3$; rhodonite, the silicate $MnSiO_3$; psilomelane, the hydrated binoxid $2(MnO_2)H_2O$.

Reduction.—Mix pure oxid and carbon and subject the mixture in a plumbago crucible to the highest heat possible or reduce the mixture in an electric furnace. The metal may, however, contain some carbon and silicon.

An alloy of iron and from 5 to 30 per cent of manganese and from 4 to 7.5 per cent of carbon is known under the name of spiegeleisen.

Ferromanganese is a similar alloy containing from 30 to 85 per cent of manganese.

Uses.—Ferromanganese is now generally used in the manufacture of Bessemer steel for deoxidation, desulphurization, and to some extent recarburation. The peroxid is employed for the production of chlorin gas Numerous manganese compounds are of daily industrial and scientific employment.

Iron.

Iron is of a light bluish-gray metallic lustre, is tough, malleable, and ductile, and is susceptible to be magnetized.

The ores of industrial importance are:

Specular iron ore, Fe_2O_3; limonite, brown hematite, bog ore $2(Fe_2O_3)3(H_2O)$; magnetite, Fe_3O_4; siderite, spathic iron ore, $FeCO_3$.

Most of the ores are directly reduced in blast furnaces by coke or charcoal mixed with a flux, mostly carbonate of lime, for fluxing the foreign substances nearly always connected with the ores. Some ores are submitted to a preliminary calcination or to mechanical concentration. From the blast furnace an impure iron known as pig iron is obtained, the impurities consisting of various proportions of carbon, silicon, sulphur, manganese, phosphorus, here and there, but generally seldom, copper, chromium, nickel, cobalt, etc

Puddling.—The melted cast iron covered with a layer of liquid slag is kept under constant motion so as to expose constantly new parts to a current of hot air, thereby removing the greatest part of carbon and silicon and some of the sulphur. The iron, which loses its fluidity under this process, is divided into balls, passed through squeezers, hammered into bars, and then rolled in the commercial shapes of wrought iron.

Bessemer Process.—Steel for the production of rails or machine steel is manufactured by running a weighed quantity of melted and selected pig iron into a converter, where it is subjected to a blast of air under pressure. The silicon is blown out and burnt into silica in the first stage of the process. Then the carbon is burnt out, producing an intense heat. The converter, which turns on trunnions, is turned down, and its contents is poured into a ladle, into which, at the same time, a weighed quantity of ferromanganese, containing a known percentage of manganese and carbon, is thrown.

The required recarburization may be obtained by the addition of weighed melted pig iron of known contents of carbon, or by the introduction of the required carbon by some other means. The metal is poured into ingot molds.

The converter in this process is lined with a mixture of silicious stone and fire-clay, which is technically known as an acid lining.

Basic or Thomas-Gilchrist Process.—This process is identical with the Bessemer in apparatus and operation. The lining of the converter, however, is basic and consists of calcined dolomite, or of a mixture of burnt lime and magnesia. The slag formed in such converters, when a quantity of quicklime has been added to the charge, eliminates to a great extent the phosphorus contained in the iron.

Open-hearth or Siemens-Martin Process.—This process may be either acid or basic according to the lining of the hearth of the reverberatory furnace, in which selected pig iron and malleable scrap-iron is melted, with the addition of pure iron ore. The latter, together with the air, contributes to the oxidation of the silicon and carbon in the melted mass. The final deoxidation is sometimes produced by a small quantity of aluminium or of ferromanganese, which at the same time

desulphurizes and recarburizes the metal to the required extent.

In furnaces with basic lining, the roof is built with acid fire-brick and a passive joint of a few inches is interposed between the two materials. Such a joint may consist of chrome, or of about 40 per cent of chromium trioxid, 15 per cent of protoxid of iron, and 8 per cent of silica or of carbon.

An average analysis of good basic lining is: Magnesia 36, lin e 52, silica 8, alumina and oxid of iron 4.

Chrome Steel.—The chromium in this steel varies between 0.25 and 2 per cent. Very hard and of fine texture.

Nickel-steel.—Contains generally from 2 to 4 per cent of nickel and 0.2 to 0 3 per cent of carbon Armor-plate employed in the French navy contains about 0.4 carbon, 0 2 nickel, 1 per cent chromium.

Aluminium Steel.—Aluminium is mostly employed as a deoxidizing agent Any excess of aluminium in steel reduces its welding property.

Malleable Cast Iron.—Objects cast in white cast iron are packed in red hematite, Fe_2O_3, or in spathic ore, $FeCO_3$, and are kept at a red heat for several days. After cooling, the objects are found to be malleable, the combined carbon having been partially oxidized and removed, and partially converted into graphitic carbon.

Cementation and Case-hardening.—Wrought iron or finished objects of the iron are packed in powdered charcoal in boxes and kept at a red heat for from a day to a week or more, the time being dependent on the mass treated and on the depth of the cementation desired.

In case-hardening for finished articles, calcined hoof-paring or old leather are sometimes added to the charcoal powder, providing very finely divided carbon.

After exposure to the heat for a sufficient length of time, the articles are quenched in water, thereby hardening the superficial skin which then resists wear better than any other material which may be employed.

Electric Welding of Iron.

Elihu Thomson Process.—The current of low electromotive force should be about 15 amperes per sq. mm., equivalent to about 10,000 amperes per sq inch of sectional area at the place of the bar to be joined by welding.

Bernardo's Process.—The heating is effected by the arc between the object treated, which is made the positive pole, and a carbon rod provided with an insulated handle, which acts as negative pole. An arc, 6 inches long can be produced, usually the arc is about 2 or 2½ inches long; the current varying between 200 and 5 amperes at 110 to 120 volts. In this manner flanges of pipe or of plates ¼ to ½ inch thick can be sufficiently heated to be welded together. By holding the arc upon one point, a hole can be burnt in plate iron, and may be extended in any direction by the same means.

Lagrange & Hoho Process. — A lead-lined tank of wood or of stoneware is filled with a solution in water of sulphuric acid, or of sodium or potassium carbonate, or of borax, the lead lining serving as anode and the piece to be heated by plunging it in the liquid as cathode.

Burton's Liquid Forge.—A rectangular tank of non-conducting material is divided by non-conducting, perforated partitions into three unequal compartments. The smaller longitudinal compartment receives a lead plate as large as possible, serving as anode. In the small transverse compartment is put a movable plunger, filling nearly the whole space when fully depressed. This plunger serves as regulator for the height of the level of the electrolytic solution in the tank, which consists in a solution of 1.05 density of common salt (sodium chlorid) in water for light work, or a solution of 2 per cent wash soda and 0.3 per cent borax for heavier work. The object to be heated, which forms the cathode, is placed on one or two non-conducting supports over the surface of the liquid, and the plunger is depressed until the liquid comes in contact with the object to be heated. The current of about 26 amperes and 220 volts for bars 1 sq. inch is turned on; the heating is produced partly by the current and partly by the ignited hydrogen evolved.

Zerener's Heating Method.—An electric arc is formed between two carbon electrodes, inclined or forming an angle with each other. The arc is deflected downward by being placed between two poles of an electromagnet and is employed for heating the object to be treated.

Such an arc, which is similar to a blowpipe flame, has been used to braze bicycle tubes with a current of 40 to 60 amperes and 40 volts. Iron plates about ¼ inch thick may require 100 to 200 amperes by 70 volts for welding

Uses.—The uses of iron in the form of cast iron, wrought iron, or steel are so universal, so manifold, and so well known that no special mention of them need be made here.

Nickel.

Nickel has a very light yellowish-gray brilliant metallic lustre, it is tough, malleable, and magnetizable.

The sulphid ores, like millerite, NiS, and pentlandite, $NiFeS_3$, are submitted to a number of roastings and meltings, producing mattes increasing gradually in the contents of nickel. The foreign substances are gradually removed in the slag resulting from the employment of proper fluxes Arsenites, like niccolite, are similarly converted into speisses, successively enriched in its nickel contents.

Silicates, like garnierite, $NiSiO_3$ and genthite, $NiSiO_3+H_2O$, are mixed with sulphid ores and proper fluxes, and are converted by smelting into mattes.

The crude nickel, like iron, is submitted to puddling or to the Bessemer or open-hearth process. For final deoxidation an addition of a small quantity of magnesium has been found to give the most satisfactory results.

It is said that nickel ores (oxids), as anode in a suitable electrolyte with a great current density, have been treated in Canada in the Burton electric forge.

With ores containing cobalt, the roasting and smelting is followed by solution in acid from which copper, lead, and other metals are precipitated as sulphids by treatment with hydrogen sulphid The filtered solution. after being neutralized, is treated with chlorid of lime, precipitating first iron as ferric hydroxid and then cobalt as peroxid. The nickel as nickelous hydroxid is precipitated from the solution after filtration.

Nickel-carbonyl Process.—When over recently reduced metallic nickel a flow of carbonic oxid at less than 150° C. is conducted, a compound of nickel and carbonic oxid is formed, of the formula $Ni(CO)_4$. This compound condenses to a liquid at or below 43° C and is designated by the name of nickel-carbonyl. The vapors of this substance are decomposed at 180° C into nickel and carbon monoxid. Iron is the only metal known which can produce an analogous compound.

Nickel ore, thoroughly oxidized by roasting, is heated to 400° C. in a current of water-gas (gas obtained by decomposition of steam in a gas-producer), which reduces the oxid to the metallic state. The ore is then conducted through air-tight flues into a vertical drum containing carbonic oxid, where it falls over a number of shelves to the bottom, the temperature in the drum being at not above 80° C. The vapors of nickel carbonyl so formed are conducted into pipes, heated to 180° C., in which the metallic nickel is deposited on the walls and the liberated carbonic oxid is returned to the combining drum by a fan From the bottom of the drum the ore is conducted to the reducing apparatus and, with a new portion of metallic nickel produced, is subjected to a repetition of the operations described.

Uses.—Pure nickel is used in plating and for numerous utensils Parts of light machinery and ornamental parts of household utensils are generally nickel-plated An alloy with copper and other metals is used for coins and for German silver. It is used alloyed with steel in armor-plate

Cobalt.

Cobalt has a light steel-gray metallic lustre, has little malleability. The metallurgy of its ores is substantially the same as that of nickel ores with which it is nearly always associated.

Uses.—With the exception of some beautiful blue coloring-matters, cobalt is hardly used industrially

Platinum.

This metal is of a grayish-white metallic lustre, is tough and very malleable and ductile.

The metal is nearly always found native, sometimes alloyed with other metals, principally iridium. It is dissolved in

strong aqua-regia, the solution is treated with an excess of hydrochlorate of ammonia, thereby forming a light yellow precipitate of the double chlorid of ammonia and platinum. By calcining this precipitate, elevating the temperature gradually to a red heat, the metal is obtained as a gray porous mass, which is purified from traces of iridium by redissolving in aqua regia, repeating the precipitation and calcination. Iridium remains undissolved in dilute acid. The finally obtained spongy mass of platinum is compacted by pressure and hammering and wrought into the desired shape by welding.

Uses.—It is mainly used for apparatus in the chemical industries and in laboratories, for electrodes in batteries and in electrometallurgical apparatus, in incandescent lamps as connecting wires, and in blowpipe analysis as wire, foil, and crucible, and for a great variety of other scientific applications.

33. METALS.

Discovery and

(Abbreviations W.H.—white heat; E.—evaporates;

Reference No.	Name of Metal	Name of Discoverer	Year of Discovery	Condition of Metal	Specific Gravity, Water at 60° F.=1
1	Aluminium	Woehler	1828	cast,	2.587
				rolled	2.7
2	Antimony			pure	6.8
3	Arsenic			"	5.88
4	Barium			"	4.5
5	Bismuth			"	9.8
6	Cadmium			"	8.7
7	Calcium			"	1 58
8	Cobalt	Brandt	1733	"	8.54
9	Chromium	Vauquelin		"	6.7
10	Copper			"	8 93
11	Glucinium	Woehler		"	2.1
12	Gold			"	19.425
13	Iridium	Descotils	1803	"	22 38
14	Iron			"	7.79
				cast	7.125
	"			wrought	7 7
15	Lead			pure	11.445
16	Lithium			"	0.59
17	Magnesium	Bussy	1829	"	1.75
18	Manganese	Gahn, Scheele	1774	"	8
19	Mercury			"	13.596
20	Molybdenum			"	8.63
21	Nickel	Cronstedt	1751	"	8.8
	"			cast	7.8
22	Palladium	Wollaston	1803	pure	11.8
23	Platinum	Wood	1741	"	21.52
24	Potassium	Davy	1807	"	0.87
25	Silver			"	10.5
26	Sodium			"	0.972
27	Tin			"	7.3
28	Tellurium	Klaproth	1782	"	6.11
29	Tungsten	D'Elhuyart	1781	"	17.6
30	Uranium	Peligot	1842	"	18.4
31	Zinc			"	7.19

Physical Properties

R. = refractory; F = Fahrenheit; C. = Centigrade)

Linear Expansion from 0° to 100°C 32° to 212° F.	Melting point, Degree		Specific Heat, Water at 0° C. = 1	Conductibility, Silver = 100		Reference No.
	F.	C.		Heat	Electricity	
0.00206	1160	630	0.2185	38.4	54 2	1
0.00108	842	450	0 0508		4	2
	E.	E.	0 0814			3
						4
....	....490...	....254.	...0.0308....	...1.8..	...1.2	5
	608	320	0.0567			6
						7
		W.H.	0.10696			8
						9
..0.001718..	..1890...	..1032.	.. 0.0925....	. 73.5..	..99.9.	10
						11
0.001415	1863	1017	0 03244	98	78	12
0.000641		R.	0.1837			13
	4090	2200	0.1138	12	16.8	14
0.001220						
..0.002857..	....630...	....332...	...0.0314...	...8.5..	...8.9.	15
	356	180				16
		433	0.2499		41.2	17
		W.H.	0 1217			18
0.00018	−38	−39.8	0.03332	5.33	1.63	19
....	....	..R....	...	....	....	20
0.00125		W.H.	0.1086		13.1	21
0.001		W.H	0 0593	6.3	18.4	22
0.000884	3195	1957	0.0335		10.6	23
	112	62 5	0.1695			24
..0.0019....	..1840...	..1023 ..	...0 057.....	.100....	.100. .	25
	205	97	0.2934			26
	442	228	0.5695	14.5	15.45	27
	625	324				28
		R	0.03636			29
		R				30
0.002942	779	415	0.0955			31

34. PRECIOUS STONES.

Approximate Order of Valuation of Precious Stones: 1. Pearl; 2. Ruby; 3. Diamond; 4. Emerald, sapphire, oriental cat's-eye, precious opal; 5. Alexandrite, jacinth, oriental onyx, peridot, topaz, zircon.

Defects in Precious Stones.—1 Feathers: little rents or fissures in the inside; 2. Clouds: gray, brown, or white spots resembling clouds; 3. Sands: small bodies like seeds or grains of sand of white, brown, or red color; 4. Dust: fine sand disseminated in very fine particles in a stone.

DIAMOND FIELDS.

South Africa.—An approximate circular area, surrounded by horizontal shales with upturned margins around the area, constitute the site of each diamond mine. The surface was originally covered by a reddish, sandy soil, covering a calcareous tufa or light deposit of carbonate of lime, to the under surface of which diamonds were occasionally found to be adherent. This was followed by an altered volcanic rock, much broken up in places, and decomposed and oxidized on its upper surface into what was denominated "yellow earth." The blue rock known as "blue ground" below carried the greatest part of the diamonds, and is considered by some scientific men as its matrix. Under this rock as a base is a soft mineral of green or bluish color and soapy to the touch. The diamond-bearing rock contains, in addition to diamonds, altered fragments of shale and various minerals, as: Pyrope (chrome garnet), diopside of bright-green color, chromite, enstatite, mica, vaalite, zircon, cyanite, magnetite, titaniferous iron ore, barytes, hornblende.

The reddish, sandy soil of the surrounding country is underlaid with a decomposed basaltic rock resting on a layer of carbonaceous shale of about 200 to 250 ft. thickness, and under it a bed of conglomerate on an amygdoidal old lava flow of about 400 ft. thickness, below which is quartzite of unknown thickness. These rocks are here and there penetrated almost vertically by igneous dykes.

The four mines, DeBeer's, DuToit's Pan, Kimberley, and Bultfontein, are the principal mines. The aggregate yield of

diamonds during the year ending March 31, 1890, was 1,608,830 carats, realizing the sum of $2,641,557.

Every load of blue ground of about 1600 lbs yields on an average:

From the Kimberley Mine $1\frac{1}{4}$ to $1\frac{1}{2}$ carats; from DeBeer's Mine $1\frac{1}{5}$ to $1\frac{1}{3}$ carats; from DuToit's Pan mine $\frac{1}{6}$ to $\frac{1}{5}$ carat; from the Bultfontein mine $\frac{1}{5}$ to $\frac{1}{3}$ carat.

Rare Diamonds.

A diamond of $83\frac{1}{2}$ carats rough, $46\frac{1}{2}$ carats cut, obtained from a Kaffir medicine man by Van Niekirk, was sold by the latter for $56,000. A stone of 112 carats rough, 66 cut into a brilliant, has been acquired by the King of Siam.

A stone of 124 carats was found at DuToit's Pan. July 21, 1871.

A stone $288\frac{3}{8}$ carats rough was found in 1872 by a Mr. Antoine on the Vaal River, on a claim originally owned by a Mr. F. Pepper, who sold the claim for $150 to a Mr. Spalding, and the latter turned it over to Antoine to work it on shares.

A $209\frac{1}{4}$ carat stone, it is said, was purchased by an illicit diamond buyer for $75 from a Kaffir

On February 12, 1880, on a claim at Kimberley, a stone of 150 carats was found with a faint tinge of blue It was valued at $1,000,000.

The largest stone, of $428\frac{1}{2}$ carats rough, was exhibited in 1889 in Paris, where it was cut to a brilliant of $228\frac{1}{2}$ carats.

About 20% of the Cape diamonds are of first quality, 15% of second, 20% of third. The remaining 45% is considered to be "bort."

Brazil.—At **Diamantina,** formerly **Tejuco, province of Minas-Geraes,** diamonds were originally discovered. They are also found near Grao Mogol, province of Minas-Geraes, and at the Chapada Diamantina in Bahia.

The washings are performed on old river gravels or on gravels taken from the bed of rivers.

Anatase, rutile, brookite, specular iron, topaz, tourmaline, and gold are found associated with the diamonds in the gravel.

At **São João da Chapada,** twelve miles west of Diamantina, the diamonds occur in clay, called "barro."

On the **Corrego dos Bois** near **Grao Mogol** they are found in conglomerate rock, called pigeons' eggs.

In **Bahia** are also found the black, gray, or brown carbons, known as carbonado, used for diamond drills.

Up to 1850, the province of Minas-Geraes had yielded 5,844,000 carats of diamonds, valued at $45,000,000. To this must be added the contraband trade estimated at $10,000,000, bringing the value up to $55,000,000. For all Brazil to 1850, 10,000,000 carats.

It is estimated that in 10,000 diamonds collected from the washings rarely one of 20 carats is found, while 8,000 of 1 carat and less may occur.

In 1851 a stone of 120⅝ carats was found at the source of the Patrocinho River, Minas-Geraes. Somewhat later a stone of 107 carats was discovered on the Rio-das-Velhas, and in Chapada one of 87½ carats. The "Star of the South," of 254½ carats, was found in 1853 at Bogagan, Minas-Geraes.

From 1861 to 1867 the estimated value of the Brazilian diamonds was about $9,440,000.

India.—Diamonds are found in superficial deposits of disintegrated rocks; at the Panna and Banaganpilly mines in conglomerate of detritus and pebbles.

On the river Pennar near Cuddapah the surface is covered with a mixture of sand, grit, or loam 1½ feet thick, underlaid by 4 feet of tough blue or black muddy earth free of stones, and under this the diamond bed, 2 to 2½ feet thick, with numerous large round stones embedded in it, consisting of pebbles and grit cemented by loam.

The Hindoos classify diamonds as follows:

1. Brahma clear, of pure water.
2. Chedra clear, honey-colored.
3. Vyesa, cream-colored.
4. Sudra, grayish white.

At the west side of the Nalla-Malla hills as far as the town of Randial, the beds of the diamond mines are only about 1 foot thick, the over and underlying beds being pebbly.

At Banaganpilly, five hours' journey west of Randial, the diamond layer of the mines is, according to Dr. King, Director of the Geological Survey, a clayey conglomerate with pebbles, shales, quartz, and chert fragments.

The "Great Mogul," according to Tavernier, was, rough, of 787½ carats and was reduced by cutting to 279$\frac{9}{16}$ carats.

Borneo.—The diamonds are found in the sands of rivers, in beds of clay, sand, and gravel. In the same rivers gold, and sometimes platinum, is found.

Australia.—In New South Wales, on the Cudgegong River, nineteen miles northwest of Mudgee, diamonds are found in gold-bearing drift, in most places covered by a basaltic cap. In the gravel are found quartz pebbles and boulders, rock crystal, jasper, agate, tinstone, coarse sand, and clay, and here and there after diligent search, ruby, sapphire, topaz, zircon, garnet, spinel, pleonaste, etc. Most of the diamonds, however, are small, the largest being only $5\frac{5}{8}$ carats rough and $3\frac{5}{16}$ carats brilliant cut.

Near Bingera, 400 miles north of Sydney, on the river Horton, diamonds occur in an old river drift which in some places is compacted into conglomerate. The stones are small, from $\frac{1}{8}$ to $1\frac{1}{2}$ carats.

In the tin-mining districts near Iverell, and in the drifts of Vegetable Creek in New England district, also near the junction of Cope's Creek with the Gwydir, numbers of small diamonds have been found, the largest of which may have been between 2 and 3 carats.

COLORED DIAMONDS.

Colored diamonds rank in value as follows: 1. Red; 2. Green; 3. Blue.

There are many rose-colored diamonds, but bright-red or ruby-red ones are extremely rare. One of 1 carat, known as the Halphen red diamond, bought by a jeweler of London and sold by him to a connoisseur, is almost the only specimen known to jewelers. It is said that a fine red diamond was found in Borneo and sold for a large sum in Paris.

A green diamond, thrown out of a parcel of emeralds, was bought for a trifle in Vienna by an Englishman, sold to a London jeweler for $1,000, resold by him a few years afterward for $1,500, and again sold by another London jeweler for $3,000 to an American. Afterward $5,000 offered for it was refused.

In Dresden in the Gruene Gewölbe is a faded green diamond of $48\frac{1}{2}$ carats valued at $150,000.

Bluish diamonds are not uncommon, but they are often

not quite transparent, and these are, therefore, considered as inferior stones

Until lately the only deep-blue stones were found in the Indian mines. The blue stone said to have been bought by Tavernier in 1642 weighed in the rough 112¼ carats It was sold to Louis XIV. in 1668, and is supposed to have been cut into a faceted diamond of triangular shape weighing 67½ carats. A stone of this kind was deposited in 1792 with the rest of the French regalia in the Garde Meuble and disappeared. In 1830 a stone of the same color appeared under the name of "Hope Diamond" cut into a brilliant of 44¼ carats. A stone of the identical same color of about 6 to 7 carats was sold in Geneva at the sale of the jewels of the Duke of Brunswick in 1874, and a third stone of the same color of 1 carat was bought by a London jeweler in Paris for $1,500

These three stones are supposed to have originally been part of the blue diamond missing from the French regalia deposited in the Garde Meuble in 1792.

Bort or *boort* is the name given to diamonds of inferior quality imperfectly crystallized and useless for ornamental purposes. Such diamonds, usually of a grayish-white color and showing a radiated structure on fracture, are crushed and used in the form of powder as abrading material by the lapidary for grinding and polishing precious stones.

Carbonado, carbonate, or carbon are names given to dark-gray or even black diamonds of superior hardness which are used principally for diamond-drilling tools.

ROUGH DIAMONDS.

Classification and Names in the Market of London.

White clear crystals	Bright brown
Bright black cleavage	Deep brown
Cape white	Bort
Light bywater	Yellows
Large white cleavage	Large yellows
Picked melée	Large bywaters
Common and ordinary	River stones, fine quality
Melée	Jagersfontein stones
Bultfontein melée	Splints
Large white chips	Emden
Mackle, or macle	Fine fancy stones

RUBY.

Ruby, sapphire, oriental amethyst, oriental topaz, corundum, and emery are chemically the same substance, known as alumina, an oxid of aluminium, the chemical formula of which, Al_2O_3, indicates its composition by weight to be: aluminium, 54 parts; oxygen, 48 parts; or Al 52.94 and O 47.06 per cent.

Crystallized alumina when colored a more or less brilliant red is ruby; when blue, sapphire; when violet, oriental amethyst; when yellow, oriental topaz; when pure, colorless, and transparent, corundum.

The ruby ranks in price above all other stones. A perfect ruby of five carats will command a price ten times that of a diamond of the same size. Such a ruby of ten carats or more is considered to be almost invaluable.

Ruby Fields.—The localities yielding rubies of commercial value are for the present limited to Burma, Siam, and Ceylon.

Burma. Mining for rubies is carried on in the valleys, on the hillsides, and in caverns.

The valleys appear to be beds of former lakes gradually filled up by detritus from the surrounding mountains. Below a flat alluvial soil of 15 to 20 feet thickness is the ruby-bearing clay 4 to 5 feet thick, but occasionally thinning out to a few inches only. This is generally underlaid by a stratum of soft stone, called by the miners "rotten stone." The mining is done by digging pits of 9 or 6 feet square lined with bamboos held in place by struts. The clay extracted is washed in wooden troughs, about 5 feet in length, roughly closed at the lower end by stones.

On the hillsides the top soil, generally a marlly clay, is removed by washing. The ruby-bearing clay, often 15 or 20 feet thick, of yellowish-brown color, being very stiff, is undercut, broken off, and then shoveled on a prepared area under a stream of water for washing. In this clay are intermixed sand, gravel, boulders of rock quartz, feldspar grains of various colors, rubies, sapphires, spinels, tourmalines, graphite, mica flakes, and other minerals.

In outcroppings of the calc-spar, forming the base of the mountains, or in workings on the hillsides, caverns or caves are often found in some places solidly filled with the ruby-bearing

clay. The ramifications of these caves may extend for miles. In places the clay is covered by stalactitic formations in large, apparently empty rooms, the walls of which glisten with calcite crystals.

Rare Rubies and Compensation to Finders.—Gna Monk, an itinerant peddler in Burmah, received in exchange for a rupee's worth of his goods a red stone from the wife of a man who had found it in his rice-field He recognized it as a ruby and broke it in two, sending one part to the king Mindoon Min. The other part was sent for sale to Calcutta. The king, who, in accordance with law and custom, should have received the whole stone, noticed the deception and ordered Gna Monk and his whole village to be tortured. He later heard that the other part of the stone was in Calcutta, and had it purchased at an enormous price. After being cut in Burmah, one of the two portions, weighing 98 carats, was named *Gna Monk*, the other part, of 74 carats, became known under the name of Kallahpyan, meaning returned from India.

A stone of 400 carats was sold for 3000 rupees by the wife of a man who found it while working on a road leading to Momeit. The purchaser broke the stone in three parts. One part, after being cut in Calcutta, weighed 70 carats and was sold in England. The second part when cut weighed 45 carats and was purchased in Mandalay. The third part was sold in Calcutta for 70,000 rupees.

The stone, which is said to be the finest ever seen, weighing in the rough 44 carats and when cut 20 carats, and named Gnaga Boh (The Dragon Lord) was found at Bawbadan and given to King Tharawadis, and is supposed to have passed into the possession of Theebaw.

A fine stone of 100 carats in the rough was found on Pingtoung Hill and was presented by Co-dwa-gee to Theebaw soon after he became king.

A rich-colored stone of 37 carats, cushion shape, and another stone, 47 carats, of blunt drop shape, were brought to Europe in 1875. They were recut in London, so that the 37-carat stone was reduced to $32\frac{5}{16}$ carats and the 47 to $38\frac{9}{16}$ carats, and were so much improved that they were considered the finest stones in color yet seen The smaller stone was sold for $50,000, the larger for $100,000. Two such rubies have never been seen at the same time in Europe, and

there is no royal regalia in Europe which can display the like of them.

In the Russian regalia is a ruby the size of a pigeon's egg, which was presented to the Empress Catherine by Gustavus III. of Sweden on a visit to St Petersburg in 1777.

A ruby the size and form of half an egg cut *en cabochon* is mentioned with great admiration by Chardin. It has the name Thelk Lephy engraved on the end.

Two engraved rubies, one with the head of Jupiter-Serapis, the other with a full-length figure of Minerva-Poliada, were in the Exhibition of 1851 from the Hope collection.

Siam Rubies.—The ruby mines are in two principal groups, those of Bo Navong and those of Bo Channa. At Bo Navong, province of Kvat, the surface of the mining district of about two square miles consists of a coarse yellow or brown sand resting on a bed of clay. In the sand in a layer of 6 to 10 inches above the clay the rubies are found. The mines are holes of from 2 to 4 feet in depth.

At Bo Channa the ruby-bearing layer is from 6 to 24 inches thick. Some of the pits are 20 feet deep.

Ceylon Rubies.—The rubies are found in detritus in the valleys and in the sands of rivers in the neighborhood of Ratnapura and Rakwena. The stones are generally of very pale color and of little value as gems.

The Indian cuts the stone for weight, while the European cuts it for effect and beauty. The part of a cut stone above the girdle should be one third, while the back should be two thirds, of the whole thickness in order to produce the best effects

THE SAPPHIRE.

Under the term sapphire are included corundums of any color or tint except red, but more especially those of a blue color similar to that of the corn-flower The red corundums, as we have seen, are known under the name of rubies. There are green, yellow, gray, and even colorless sapphires, the latter being liable to be mistaken when skillfully cut for diamonds

The sapphire-yielding localities now worked are Siam, Burmah, Cashmere, and Ceylon Those from Siam are considered the finest. Those from Burma are too dark. Cashmere has furnished some fine stones, but a great many are grayish blue,

and the stones from Ceylon are too light colored to be of great value. Stones from Montana have greenish and other tints.

The imperfections of the sapphire consist in clouds, in variously colored and milky half-opaque spots, in white glassy strips, in rents, knots, silky flakes. A sapphire of a purple tint will show the "silky" defect and the stone of greenish color will have the "milky flaw" in most cases.

Siam Sapphires.—These stones are principally mined in the province of Battambong, and associated with rubies in Chantaboon and Krat.

The Bo Pie Rin mines in Battambong furnish about five eighths of the sapphires. The stones are of an unrivalled velvety-blue color, generally richer in the large than in the smaller stones. In the Phelin Valley the sapphire-bearing layer is clay, mixed with but a few gravel stones, about 2 feet under the surface.

The gem-bearing country of Siam comprises an area of about 100 square miles, the port of Chantaboon being the trade centre.

A company organized in 1890, who work the mines systematically, consigned 30,000 carats to London in 1892.

Burmah Sapphires.—They are found associated with rubies and are generally of a dark color.

Cashmere.—A landslide having laid bare the rock, sapphires were discovered about the year 1880 in the neighborhood of Padar. The sapphires were found in granitic detritus, high up in the mountains in the sides of a valley.

Ceylon.—The stones are found in river-beds or in beds of gravel 6 to 20 feet below the surface. Some of the sapphires are white, some yellow, and others are party-colored; the blue ones are often of pale color.

Montana, U. S.—Sapphires are found in old river terraces, mostly near the bed-rock along the Missouri River for a distance of about 15 miles. These old river terraces are covered with alluvial deposits of sand and gravel from a few inches to 20 feet thick. The stones are greenish, blue, and red of various shades.

Sapphires are found in many parts of Australia, in Borneo, Madagascar, in the Ural Mountains, and in many parts of Europe. The European sapphires, however, are of no commercial value except for scientific purposes.

Star Stones.—Rubies or sapphires which display, when cut *en cabochon*, a starlike reflection are known under the name of star stones. Their value is determined by quality and color.

Spinel and Balas Rubies.—Spinels occur in a great variety of colors as carmine-red, rose-red, reddish brown, orange-green blue, purple, puce, violet, and here and there white and yellow., There are stones which are opaque, dark-colored, and even black, but these are not used as ornamental stones.

The main peculiarity of the spinel consists in the phenomenon of the pale-yellow color of the light reflected from the depth of the stone, whatever its color may be.

Spinel is found along with ruby in Burmah, Ceylon, and Siam, in the ruby earth and imbedded in calc-spar, often in fine octahedral crystals; in Afghanistan in micaceous crystalline limestone; in Tartary in the famous mines of Balas Ruby at Badakshan and Usbekistan; in Victoria in the Ovens River; in New South Wales in auriferous deposits on the Cudgegong, Peel, Macquarie, Severn, and other rivers. Some have been found, of no value, however, to the jeweler, in Bohemia, Transylvania, and in Sweden.

Balas or Balais ruby is a pale or rose-red spinel with a blue tinge at the angles of the octahedron.

Pleonaste, an opaque black variety, is not used as a gem.

The spinel is a compound of alumina and magnesia of the chemical formula $MgOAl_2O_3$; alumina, 71.126; magnesia, 28.874 per cent.

Emerald.—The crystalline form of the emerald is a six-sided or hexagonal prism without striations. The color is bright green, sometimes grass-green or greenish white, which is resolved by the use of the dichroiscope into yellowish green and bluish green The coloring is supposed to be due to oxid of chromium, which enters into its constitution.

The emerald, the beryl, and the aquamarine are chemically substantially the same mineral, and their main characteristics, are in color and other qualifications important to the jeweler.

Emeralds are found on the Asiatic side of the Ural Mountains and very fine stones are found in the mica schist at Stretnisk, on the river Takowja, north of Ekaterinburg.

They occur in the mountains of the Sahara in mica schist; in the bed of the river Harrach; in Algeria in lamellated lime

stone; in the Heubachthal, in Salzburg, in mica schist; at Suarum, Norway.

The most important mines of this mineral are in the Republic of Colombia, about 75 miles N.N W. of Santa Fé de Bogota at Muzo Discovered in 1555, the mines are now worked by a company who pay $24,000 annually as rent to the government.

The matrix of the emerald at the Muzo mines is a bituminous limestone rich in carbon, resting on red sandstone and clay slate. The emeralds are found in pockets, and the mining is therefore very precarious.

In accordance with the chemical formula of the emerald, $3(GlO).CrO.Al_2O_3 6(SiO_2)$, its composition in per cent is:

Glucina	13.51
Alumina	18.01
Chromic oxid	12.25
Silica	56.22
	99.99

Aquamarine or Beryl.—Occurs in various parts of the world in granite mountains, in micaceous clay, etc. They are distinguished according to shade and color: In aquamarine, light sky blue; Siberian aquamarine, faint light greenish-blue; aquamarine chrysolite, greenish yellow or yellowish green; and in Beryl, light yellow of different shades Composition: Silica, 67; alumina, 19; glucina, 14; hardness, 7.5; specific gravity, 2 7. Hexagonal.

In a collection, exhibited for some years in the Kensington Museum, was one of the finest stones of 3½ ozs weight, said to have belonged to Prince Murat. It is a sword-hilt, beautiful and perfectly pure in color, and a unique specimen of the lapidaries' art. An aquamarine, with an engraving of a female holding a bagpipe, light drapery floating around the upper part of the body, is in the same collection.

An aquamarine $2\frac{1}{16}$ by $2\frac{5}{8}$ inches adorned the tiara of Pope Julius II.

Phenakite.—This mineral is found in mica schist and graphite in the Urals, in Siberia, and at Pike's Peak, in Colorado.

Clear, transparent, and colorless specimens are occasionally

used as gems, and when skillfully cut have great brilliancy, resembling somewhat the diamond. It is remarkable for the large amount of glucina it contains.

Composition: silica, 54.2; glucina, 45.8; hardness, 7.5–8; specific gravity, 3; Orthorhombic.

Zircon, Jargoan, or Hyacinth.—The jargoans are the dull colored smoky varieties of which the finest have yellow, brown, and green tints while the hyacinths or jacinths are transparent, of a bright red and brown color.

Zircon is found in a great many localities, but only a few furnish stones that can be used as gems. The best stones are from Cananore, Calicut and Cambia. Some fine ones have been obtained from New South Wales and Ceylon.

A zircon of 2 by 1¼ inches of unsurpassed workmanship, with Moses and the two tables of the law engraved on it, is at the Museum of Paris.

Composition: silica, 34; zirconia, 66; hardness, 7.5; specific gravity, 4–4.86. Tetragonal.

Chrysoberyl.—There are three varieties of this mineral: the chrysoberyl, the true oriental cat's-eye or cymophone, and the alexandrite. Color, light green, brownish yellow, dark yellow-brown, brownish red.

It is found in the same formation as topaz and corundum; in Ceylon in the river sands; in Burmah and Borneo among pebbles; in Brazil in the diamond sands. In Connecticut, U. S., it has been found in well formed tables and prisms, and in New York State at Saratoga and Greenfield in regular twin crystals. When transparent it is strongly double refractory. Its composition is alumina, 78; glucina, 18; ferrous oxid, 4.

The True Oriental Cat's-eye.—The true oriental cat's-eye is a rare variety of chrysoberyl, and is characterized, when well polished, by a peculiar ray of light or line of light shining with a phosphorescent lustre. Its colors vary from pale straw through all shades of brown and from pale apple-green to the deepest olive green and in some specimens almost to black. The reflected line of light is nearly always white, whatever the ground-color of the stone may be. In some specimens it has a golden hue, which is specially vivid in sunlight or gas-light.

The gleaming streak should cross the middle of the stone and move as the stone is moved.

The chrysoberyl cat's-eye is principally found with other gems in Ceylon.

Its composition, according to its chemical formula, $GlOAl_2O_3$, is glucina, 20; alumina, 80 per cent; a trace ot oxid of iron as coloring matter.

In addition to the true oriental cat's-eye, which is a fibrous variety of chrysoberyl, there are three minerals known under the name of cat's-eye, all, however, of inferior hardness and inferior specific gravity and of a dull lustre. They are: 1, a chatoyant quartz from India; 2, a green asbestiform variety from Bavaria; 3, a brown crocidolite from South Africa.

Alexandrite.—Although originally discovered in Russia, the main source of supply is Ceylon. The stone is strongly dichroic; it has a bright green or deep olive-green color as seen by daylight, which, when seen by candle- or gas-light, changes into a deep red of a raspberry tint. Some display the lustrous line characteristic of the cat's-eye, but only when they are cut *en cabochon*.

Its composition is substantially that of the chrysoberyl: glucina, 18; alumina, 79, and as coloring matter iron, chromic, copper, and lead oxid, 3.

THE TURQUOISE.

Turquoise mining at Khorassan, in Persia, in the district of Bar-i-Maden, province of Nishapur, is carried on in galleries and shafts, in veins in the eruptive and metamorphosed rocks of the mountains of the district. These rocks are mainly composed of limestone and sandstone resting on clay slates, broken through in places by porphyries and green stones in which the veins occur Diggings in the detritus of the disintegrated rock washed down in the valleys compose in part these mines. There are more than twenty mines with shafts and galleries on these mountains, some of which are very extensive, but most of them are now abandoned. The mining in the detritus on the lower slopes of the mountains and in the valleys is done in a promiscuous manner.

Turquoises have been found at Los Cerillos, New Mexico, in small veins or as nuggets covered with white porous crust. An old excavation has been dug by the Indians in the solid rock 200 ft. deep. In Arizona this mineral occurs at Turquoise Mountain and in Mineral Park

At Victoria it has been discovered some time ago and is mined in the "New Discovery Mine"

The turquoise of best quality is of a sky-blue color, which does not fade on exposure or change in artificial light. It is not transparent, but has a peculiar translucency.

Bone turquoise or odontolite is considered to be fossil bone or ivory colored blue by phosphate of iron. It is softer than the true turquoise and emits an odor when gently heated.

The callaite also resembles turquoise but has a lighter and a duller color, without its vivacity and fineness.

The chemical composition of the turquoise is:

Phosphorus pentoxid	32.8
Alumina	40.2
Water	19.2
Copper oxid	5.3
Iron and manganese oxids	2.5

Rare Turquoises.—In Russia one proverb says: "A turquoise given by a loving hand carries with it happiness and good fortune." Another says: "The color of a turquoise pales when the well-being of the giver is in danger."

According to Nicols a turquoise of the size of a hazel-nut with the image of Julius Caesar engraved on it was in possession of the Duke of Etruria.

The duke of Orleans owns two: one with the image of Diana and the other with that of Faustina.

In 1808 was sold a magnificent necklace of turquoise of twelve stones, each having the figure of one of the Caesars engraved on it.

GARNET, CARBUNCLE.

Cinnamon Stone.—The precious garnet is sometimes called "almandine." The color is blood-red, cherry-red, or brownish red, with a violet tint by candle-light

Garnets occur in a great many localities They are found in serpentine, in chlorite slate, mica schist, granite, hornblende, schists and gneiss, in glacier streams, and river beds; in Europe, Asia, America, Australia, and Africa

Mineralogists distinguish the following varieties, all of the same crystalline system and form: precious garnet, almandine

or carbuncle; the essonite, jacinth or hyacinth; the pyrope, or Bohemian blood-red garnet; the Uwarowite, or green garnet; the almandine, or carbuncle.

This stone is of a rich bluish-red color. The name carbuncle is applied to it when the stone is cut with a convex, more or less rounded face (*en cabochon*), the lower face sometimes concave, flat, or with facets, and occasionally foiled with silver or gold. Almandine is occasionally found asteriated with a six-rayed star.

Composition: silica, 36.5; alumina, 21; iron oxid, 34.5; magnesia, 4; lime, 3; manganese oxid, 1. Crystalline system and form, isometric: dodecahedron and trapezohedron. Hardness, 7; specific gravity, 3.5 to 4 3

Pyrope.—Of a yellowish dark-red color. They occur in serpentine in Bohemia and Saxony, and are sometimes found in the diamond mines of South Africa and are termed African rubies.

Composition: silica, 41.5; alumina, 22; magnesia, 15; iron protoxid, 9 5; lime, 5; chromium sesquioxid, 4.5; manganese protoxid, 2 5; hardness, 7.5; specific gravity, 3.7-3.8.

Essonite.—The name applied to this stone changes in accordance with its color: cinnamon stone, of a light cinnamon or yellowish brown; jacinth, reddish-yellow brown; hyacinth, bright-red yellow-brown; grassularia, green.

Essonite is found in Switzerland, in Piedmont, in New Hampshire and Maine, U. S., in Mexico, in Ceylon, in Siberia, etc.

Composition: silica, 40; alumina, 23; lime, 32; oxid of iron, 5; hardness, 7; specific gravity, 3.4-3 7.

Uwarowite.—Of fine bright green, is found in the Ural Mountains in gold-washings, but only in specimens of small size.

Composition: silica, 37; lime, 33; alumina, 7; chromium oxid, 23; hardness, 7.5-8; specific gravity, 3.5.

Topaz.—Mineralogists include under this name three distinct minerals: (1) The true topaz. (2) The oriental topaz or yellow sapphire, which is in reality corundum colored yellow. (3) The false topaz, or occidental topaz, which is quartz of a yellow color.

The true topaz has been found in various colors; colorless, transparent, all shades of light blue, light green, light red, light yellow, and deep yellow. The colors, however, are not

stable and often bleach on exposure to sunlight. This stone occurs in granite, in gravel, and sands of rivers; it is often found near tin ores The localities where it may be found are distributed over the whole known world.

The Goutte d'Eau is a colorless topaz which takes a very brilliant polish when cut as a brilliant

In St. Petersburg is a crystal of topaz 4¾ inches long, 4½ wide, weighing 31 lbs.

A stone set as a signet-ring, with the portrait of Philip II and Don Carlos deeply cut in it, and one of a citron-yellow color representing an Indian Bacchus are at the Bibliotheque Nationale of Paris.

An antique topaz with a representation of Sirius of excellent workmanship is at St. Petersburg. An amulet of topaz, with the Arabian sentence "From God alone is success" bored through it, is owned at Paris.

The chemical composition of true topaz is: silicon, 15.5; oxygen, 36.8; alumina, 30.2; fluorine, 17.5; hardness, 8; specific gravity, 3.5. Orthorhombic. Rhombic prism.

Spodumene, Hiddenite.—Grayish to greenish-yellow, transparent to opaque. Hiddenite has a brilliant green hue.

Occurs in many localities, but transparent specimens, the only ones of value as gems, have only been obtained in Brazil.

Composition: silica, 64.5; alumina, 29; lithia, 5.5; iron oxid and soda, 1.0; hardness, 7; specific gravity, 3. Monoclinic.

Iolite, Saphir d'Ecau.—Ceylon furnishes the best transparent specimens of various shades of blue and violet. The tint of the crystal varies when seen from different direction, the mineral being dichroic.

Composition: silica, 49: alumina, 34; magnesia, 9; ferous oxid, 8; hardness, 7; specific gravity, 2.6. Trimetric.

Andalusite.—Found in Brazil in clear crystals of green and brown color, pleochroic: showing different tints seen from different directions.

Composition: Al_2SiO_5; silica, 37; alumina, 63; hardness, 7–7.5; specific gravity, 3.1.

Labradorite.—Special specimens of Labrador feldspar, which, when polished, show an irridescent play of colors, by reflecting prismatic hues of bright green and blue, with deep yellow, reddish and bright-red reflections, to which is some-

times added a spangling brilliancy, are the only minerals of this kind employed in jewelry. The body-color is dull gray, brown, or greenish brown

Composition: silica, 52 9; alumina, 29.3; lime, 12.3; soda, etc, 5 3; , 6; hardness specific gravity, 2 7. Triclinic

Moonstone (**Orthoclase**) —This mineral occurs on the highest peaks of the St Gothard, but the best specimens are obtained from Ceylon Its lustre resembles that of mother-of-pearl.

Composition: silica, 64 7; alumina, 18 4; potash, 16.9; hardness, 6; specific gravity, 2 5–2 6 Monoclinic

Sunstone (**Oligoclase**).—Found in Norway, but rarely employed in jewelry. Its color is reddish or deep yellow, with prismatic reflections and spangling lustre.

Composition: silica, 61.9; alumina, 24 1; lime, 5 2; soda, 8.8; hardness, 6; specific gravity, 2.5–2 7.

Obsidian.—A volcanic glass, bottle-green, sometimes streaked brown, known under the name of mahogany obsidian.

Consists of silicate of alumina, potash, iron, and lime. Hardness, 6 5; specific gravity, 2 6 Amorphous.

Crocidolite.—Mainly from South Africa. When brown it is called tiger's-eye, when blue, hawk's-eye because when ground *en cabochon* the cat's-eye effect is produced.

Composition: silica, 51; oxid of iron, 34; soda, 7; magnesia, 3; water, 5; hardness, 7; specific gravity, 3 Triclinic.

Amazonite, Amazonstone.—This mineral of a beautiful bluish-green color has been mainly obtained from Siberia, but occurs at Pike's Peak, Colorado, and has been found in Scotland.

Composition: silica, 65; alumina, 18; potash, 13; soda and coloring matter, 4; hardness, 6; specific gravity, 2.5.

Peridot or Chrysolite.—These minerals are known under the general name of Olivine. When the color is light straw-yellow or yellowish green it is called chrysolite, when of a deep yellowish-green or olive color the name peridot is applied to it

It occurs in the East, South Africa, Brazil, Mexico, Arizona, U. S., and New South Wales.

This stone should be carefully polished; for the final polish and lustre sulphuric acid has to be used.

Composition: silica, 39.73; magnesia, 50.13; ferrous oxid,

9.19; nickel oxid, 0 95; hardness, 6 5; specific gravity, 3 35. Trimetric

Chrysoprase.—This stone occurs in veins of serpentine Its color is transparent yellowish green of many shades, which are liable to pale when exposed to sunlight or heat.

Composition: silica, 97 5; oxid of nickel, etc., 2.5; hardness, 7; specific gravity, 2.6. Amorphous.

Lapis-lazuli.—This mineral is found in the Cordilleras between the Argentine Republic and Chili in a thick stratum of carbonate of lime, which rests upon slates, and is covered by a deposit of iron ore in which occur garnets On top of this is granite. It is found in Siberia near Baikal Lake, in the district of the Oxus, mixed with iron ore, in many provinces of China, mixed with pyrites in granular limestone, on the Indus in grayish limestone

The stone is used for all kinds of ornamental purposes, for vases, caskets, cups, buttons, for architectural decoration in buildings, and only to a limited extent for rings, pins, etc

Composition: silica, 45 5; alumina, 31 8; soda, 9 1; lime, 3 5; iron, 0 8; sulphur, 0 9; sulphuric acid, 5 9; chlorine, 0.4; water and loss, 2.1; hardness, 5.5; specific gravity, 2.3–2.5. Massive and isometric.

Tourmaline.—This mineral is known under different names according to color The red is called rubellite; the blue, indicolite; the clear colorless crystal, achroite; the black, schorl.

In some specimens one part may be green and another part pink; some show a spot of red color surrounded by a lively green.

Tourmaline is found in Siberia, Ceylon, the Urals, Saxony, Isle of Elba, United States, Mount Mica Maine, and in Brazil.

Tourmalines of carmine, yellowish red, purple, rose-red, and reddish blue are obtained from Siberia.

Olive-green or yellowish-green stones of a more or less dark color are found in Brazil and Ceylon

Tourmaline becomes electric by friction. Those in which the crystalline structure is different at the two extremities or is hemimorphic are pyroelectric.

It is a mineral of double refraction and dichroic, showing different colors when seen from different directions

Composition somewhat variable A green stone's was as

follows: Silica, 38.55; alumina, 38.4; borontrioxid, 7.21; ferric oxid, 5.13; ferrous oxid, 2; soda, 2.37; fluorine, 2.09; lithia, 1.2; lime, 1.14; manganic oxid, 0.8; magnesia, 0.73; potash, 0.37; hardness, 7 5; specific gravity, 3-3.15

Sphene.—This stone is found in many localities, among which are many parts of North America, Arendal in Norway, Mont Blanc, and St. Gothard Mountains. The color varies from pale yellow to green, and it may be opaque and transparent. Only the latter variety can be used as a gem.

Composition: Silica, 4.1; lime, 27; titanic oxid, 41; iron oxid, 1; hardness, 5-5.5; specific gravity, 3 5 Monoclinic.

Opal.—In Hungary the opal occurs in trachitic or porphyritic rock, from which lead, silver, and gold is also obtained The mineral forms veins filling cavities in the rock. Precious opal of great beauty has been found in Queensland as veins in brown iron stone and in other parts in sandstone; also in New South Wales disseminated in a similar sandstone Mexico, Honduras, and Guatemala are also localities where opals have been found. Most of the central American opals seem to be more transparent and less flashy or fiery than the Hungarian opals.

The precious opal cannot be said to have any particular color of its own, but it has a pearly brilliant lustre which reflects and throws out rainbow tints, which in some specimens are more or less evenly distributed, while in others one part of the stone displays more particularly one shade or color and another part a different color. In other stones the colors appear more or less banded or concentrated in patches of all kinds of hues distributed over the surface of the stone; such stones are known as harlequin opals

Stones destitute of this color-play are not used as gems and are known under the name of common opal

Rare Opals.—Pliny narrates that Marc Anthony proscribed Senator Nonius because the latter was in possession of an opal the size of a hazel-nut valued at about $100,000 Nonius preferred living in exile with his opal to living in Rome without it.

Two stones were exhibited in the exhibition in Paris in 1867, one of 186 carats, the second of 160 carats, the latter a magnificent harlequin opal. Both were of drop or pear shape, and they were considered to be the finest of their class.

An opal weighing 17 ounces, as large as a man's fist, is in the Imperial Cabinet of Vienna

In the Hope collection was an opal 1¾ inches by 1 inch which was highly transparent and showed very rich colors of reflected green and yellow rays interspersed in different directions with rays of a bright blue and deep red. The figure of Apollo engraved on it in *alto rilievo* was surrounded by rays of fire

Composition: Silica, 88; water, 12; hardness, 5.5–6; specific gravity, 2–2.2 Amorphous

Rock Crystal.—Rock crystals are found in caves of granite rock in different parts of Switzerland, in cavities of the marble of Carrara This mineral is found nearly in every mountainous country. Ceylon, Madagascar, and Brazil, especially the latter country, supply it in quantities

One crystal in the Museum of Berne weighs 276 lbs and another 255 lbs

A block of crystals in the Natural History Museum of Paris measures 3 feet in diameter and weighs 800 lbs

Among the French national jewels is an urn of rock crystal 9½ inches in diameter and 9 inches high, on the upper part of which is a representation of Noah asleep, his children holding a covering, and of a woman holding a basket of fruit in her hand This urn is valued at $20,000

Composition of crystallized silica is silicon, 46.7; oxygen, 53 3; hardness, 7; specific gravity, 2 65

Carnelian.—Found in nodular masses and in the interior of agates in Germany at Oberstein, province of Birkenfeld. in sandstone, and at Waldshut, Baden, in agate gravel; as pebbles in Peataupur, East India, and in rivers in Uruguay Quantities are exported from Brazil

Carnelians are distinguished by jewelers and lapidaries by color as follows:

1. Masculine carnelian, carnelian of old stone, dark red
2. Feminine carnelian, pale red and yellowish red
3. Sard, brown to yellow
4. Sard-onyx, alternating layers of sard and white
5. Carnelian-onyx, blood red stripes and white.
6. Carnelian-beryl, whitish yellow

At Oberstein and Idar, Germany, pale-gray chalcedony is colored by chemical means a bright red and is converted into carnelian of the richest tints

This stone, besides its employment for rings, seals, watch-keys, beads, and other similar ornaments, is much used for cameo-engraving

Composition: Silica with oxid of iron; hardness, 7; specific gravity, 2 6

Agate.—This stone occurs in nodular masses filling amygdaloidal cavities in rock consisting in most cases of ancient lava and resembling in other cases basalt. Nodules of agate are also found in river-beds

The mineral has variously colored layers of all shades of brown, red, gray, green to black, and has distinguishing names in accordance with the arrangement and appearance of the colored streaks or bands The main supply now comes from Uruguay, South America, under the name of Brazilian agates, where they occur sometimes in large nodules in river-beds.

They are worked and cut into all kinds of ornamental objects in and around Oberstein and Idar on the river Nahe, a tributary to the Rhine at Bingen, Germany In the same localities great skill is displayed in dyeing stones all kinds of colors.

Composition: Silica and coloring-matter; hardness, 7; specific gravity, 2 6 Nodular, amorphous

Oriental Onyx.—This stone is similar to agate in composition and in the banded appearance of its colors. It is principally used in jewelry for cameos The stone is translucent, with banded colors, principally brown, of all shades

A kind of marble which is largely used for architectural decoration, having the same coloring and shaded bands, is known as onyx marble

Jasper.—This mineral is found in compact masses or as pebbles in kidney shape in various colors and shades of green, yellow-brown, brownish red. The colors form sometimes bands and zones

It occurs in a great many localities, and is only used for ornamental purposes when the colors are such as to produce pleasing effects.

Composition: Silica, 99.5; oxid of iron, 0.5; hardness, 7; specific gravity, 2 5.

Jade.—The color of this stone is of a bright green. Jade is found in New Zealand, and has been worked for ages in China into various ornaments It has been used somewhat for earrings and pendants and other objects of ornamentation.

Composition: Silica, 57 75; magnesia, 19.86; lime, 14.89; oxid of iron, alumina, etc., 7 5; hardness, 6.5; specific gravity, 2.91-3.18. Amorphous.

35. ORE ANALYSIS.

DRY AND WET ASSAY.

Roasting for Dry Assay.—The object of roasting an ore is to eliminate the volatile components and metals and to oxidize the non-volatile base metals

Ores of gold, silver, and copper containing considerable zinc, antimony, arsenic, or sulphur are roasted in a shallow roasting-dish over the flame of a Bunsen burner or in a moderately heated muffle The ore is continually stirred until the glow appearing after a short time or the emanation of minute sparks ceases; it is then subjected to increased heat until no more fumes are evolved, when the ore is considered to be "sweet"

In ore consisting principally of copper and iron pyrites mix after cooling a little carbonate of ammonia, cover, and heat moderately till no more fumes are expelled

If considerable sulphid of lead or of antimony is present in the ore, mix with fine sand or precipitated silica while roasting, to prevent caking or adherence to the roasting-dish

For antimonial or arsenical compounds in the ore, add some finely ground charcoal, which should be completely burned out before removal.

Scorification.—The object of scorification is to produce an alloy with lead of the precious metals in the ore.

The requisite quantity of granulated pure lead, of which the contents, if any, of silver has previously been determined, is generally divided approximately in two equal parts, one of which is intimately mixed with the reagents and the roasted or unroasted ore, as the case may be. The mixture is put in a scorifying-dish of refractory material, then evenly covered with the second half of the granulated lead, and over all some borax glass is sprinkled.

The scorifier with contents is placed in a decidedly hot muffle, which is kept closed for a few minutes until the lead is melted, when air should be admitted. When the metal in the scorifier

is well covered with a liquid slag the heat is increased for a few minutes. The operation is considered concluded when the liquid slag runs clean from an iron rod dipped into it.

Cupellation.—The object of this operation is to isolate the precious metals, gold and silver, by oxidizing the lead or converting it into litharge and removing the latter as it forms. The alloy of lead and precious metals is melted in a dish of bone ash, called a cupel, weighing from one quarter to one third more than the lead button The bone-ash has the property to absorb the litharge as it forms. The cupel is placed in the hot bright-red muffle and the lead button placed on it when the cupel is red-hot The muffle is then kept closed for about a minute, when the lead is melted, after which air should have access to the melted lead While oxidizing, or the conversion of the lead into litharge takes place, the muffle should be kept at a bright-red heat and the cupel red-hot Fumes should rise slowly from the luminous and clear surface of the metal. The heat should neither be too high nor too low. If scales of litharge "feathering" show on the inner circumference of the cupel it indicates that the heat has not been too high. When the last of the lead is oxidized and leaves the button, it is indicated by a film apparently revolving with great velocity and by rainbow colors showing on the button's surface as a final film is passing over the bead This phenomenon is known as "brightening," "flashing," or "blicking" Then increase the heat for a short while by closing the muffle-door in order to drive the last traces of lead away Let the assay cool slowly by withdrawing it gradually from the muffle

Inquartation.—The object of this operation is to produce an alloy of gold and silver in which the proportion of the silver to the gold is such that all the silver can be dissolved by nitric acid, leaving the gold as a spongy mass If the proportion of silver is too small, the surrounding gold prevents the action of the acid; if too large, the gold is left as a fine slimy precipitate. The operations consist in making the quantity of silver in the bead or button of gold-silver alloy about 2½ or 3 times as large as that of the gold, experience having shown this to be the proper quantity This is generally done by adding the necessary quantity of fine silver-foil, wrapping into sheet lead, and cupelling

Parting.—By this operation the silver is dissolved from the

gold by treating the flattened gold-silver bead or button in a porcelain capsule or crucible with nitric acid of 21° B., 1.16 specific gravity (16 parts concentrated nitric acid of 44° B. or 1.41 specific gravity to 30 parts of distilled water) for small beads. For large beads add after this treatment nitric acid of 32° B., 1.26 specific gravity (16 parts concentrated acid and 10 parts distilled water). After a while heat gently on a sand-bath, decant the clear solution when no more action takes place, and wash the remaining gold repeatedly by adding distilled water and decanting. Dry and warm to drive off the moisture, then heat well for a short time and let cool, when the gold can be weighed.

36. ASSAY OF COPPER ORE.

Dry Assay.—Ascertain if arsenic, sulphur, or both are present by roasting a small pulverized portion of the ore in the closed end of a glass tube and by observing the smell—garlic or sulphurous or both—of the gas evolved, and by noting the color and nature of the condensed deposition. If both arsenic and sulphur are present in the ore mix not less than 10 grammes or about 150 grains with half its weight of saw- or charcoal-dust and enough oil to make a stiff mixture and heat moderately in a crucible until no more arsenical fumes are evolved. Cool and triturate, expose in a shallow refractory dish to a slow roasting heat, stirring continually until no more sulphurous gases are emitted and until all the coal from the sawdust is consumed. Mix the remainder with half its weight of borax or carbonate of soda and with about one twelfth its weight of pulverized charcoal or lampblack, add oil to produce a stiff paste, which should be pressed in the bottom of a crucible. The latter, after being covered up and carefully luted, is exposed first to a dull-red heat and then for ten to twenty minutes to a bright heat in an air-furnace. The copper button obtained after cooling and breaking the crucible is refined by remelting with borax in an open crucible. To ascertain if gold or silver is present it may be cupelled with lead. From the weight of the metallic copper thus obtained the percentage of metal in the ore can easily be calculated by dividing the weight of the ore assayed in one hundred times the weight of the copper obtained

If the preliminary test does not indicate the presence in the ore of arsenic, then the first roasting is omitted, and if by the same test no sulphurous vapors are evolved, then the ore to be assayed, after being dried and weighed, is mixed with pulverized charcoal or lampblack with borax and oil and subjected to heat in the luted crucible.

FIRE ASSAY FOR SILICATES.

Oxids and Native Copper.

COMPOSITION OF FLUX AND ITS PROPORTION TO MINERAL.

Mineral		Flux					
Per Cent Copper	Grms.	Borax, Grms.	Sodium Bicarbonate, Grms.	Slag, Grms.	Potassium Bitartrate, Grms.	Sand, Grms.	Ferric Oxid, Grms.
92	100	6	5.5	20	30	—	—
86	100	6	6	18	30	—	—
60	50	10	8	—	30	—	—
[1] 35	50	14	14	—	30	—	10
33	50	15	16	—	30	15.0	—
20	50	19	20	—	30	17.5	—
[2] 5 to 20	50	20	20	—	30	—	—

[1] Tail-house mineral. [2] Rich refining slag.

The borax and soda are melted in an iron ladle to drive off the water of crystallization and then pulverized. The clean, well-fused slag from former operations is also pulverized.

The ferric oxid may be selected fragments of specular iron ore also pulverized somewhat finer.

The ordinary natural draught furnace, which can contain six Hessian crucibles of about 3 ins. diam., 4 ins. height, placed on thin fire-brick above the grate, may be used with soft coal, egg size. The crucibles, when filled, are covered with well-fitting covers of sand- and fire-clay, are charged in the already well-heated furnace, and the coal well filled in between the crucibles.

The operation should be as short as possible, about twenty minutes for easily fusible tests and from twenty-five to thirty minutes for more resisting mineral.

ANALYSIS OF COPPER ORE.

Wet Assay.—Ascertain by preliminary tests the presence of sulphur, arsenic, antimony, lead, iron, nickel, cobalt, silver, etc. If none of these is present, then the ore, an oxid or carbonate, being pulverized, is weighed and dissolved in strong nitric acid. Sulphureted hydrogen-gas is passed through the solution, precipitating the copper as black sulphid. Filter and wash the precipitate and redissolve in very dilute aqua regia (3 parts nitric acid, 2 parts hydrochloric acid); to this solution add slowly a solution of caustic potash until all the copper is precipitated as black oxid of copper Filter and wash the precipitate with boiling water and, after drying, weigh. This being protoxid of copper, CuO, is therefore composed of 63.2 parts of copper and 16 parts of oxygen

If iron only is present in the ore in addition to copper, add to the solution of the ore in nitric acid an excess of ammonia, thereby precipitating the iron as hydrated peroxid, and redissolving the precipitate of copper formed in the beginning. Filter and add the wash-water to the solution and precipitate the copper protoxid with caustic potash as stated above.

ELECTROLYTIC ANALYSIS

of Copper Ore and Copper Compounds.

The ore pulverized so as to pass through a 100-mesh sieve is carefully sampled and weighed. For ore of 20 per cent and above in copper weigh out 1 gramme, increasing this quantity as the ore is judged to be poorer, to 5 grammes for the poorest ore. For matte of about 60 per cent of copper 0.25 gramme should be taken. Dissolve in a porcelain evaporating-dish with the smallest possible quantity, or about 10 c.c. of concentrated nitric acid, and if silver is supposed to be present, add some hydrochloric acid. Cover with a watch-glass and heat on a sand-bath, driving off the free volatile acid. When cold add a little (about 5 c.c.) concentrated sulphuric acid, then heat again until red fumes cease to be evolved or until white vapors appear.

Dilute, when cold, with about 50 c.c. of distilled water, heat for a while, stirring with a glass rod, then allow the undissolved matter to settle. Pour the liquid contents in a filtering-funnel

until the residue tends to flow away. Examine the sediment, and if of a dark-colored appearance, treat it again with a small quantity of acids. Wash finally the contents in the filter and fill the latter three or four times with clean distilled water, so that all the copper solution shall be washed out of the filtering-paper and out of the funnel in the beaker below it.

The filtered copper-salt solution, may contain various other metal salts in solution, as of lead, zinc, antimony, etc., which however, do not interfere with the electro deposition of copper.

After carefully cleaning and weighing a piece of platina foil, bend into cylindrical form, destined to serve as cathode or to receive the deposition of copper, the foil is immersed in the solution and connected by a conducting wire with the negative or zinc terminal of two one-gallon gravity cells, connected in series; the copper or positive terminal being connected to the anode, consisting in a platinum wire bent into a flat spiral, dipping into the electrolyte solution.

The electrolytic deposition is continued for a whole night, or during about eight hours.

The solution is considered to be exhausted of copper when a drop of it mixed with a drop of sulphureted-hydrogen water on a clean white surface of a porcelain vessel shows no discoloration. A black coloration would indicate that copper remains in the solution, and the deposition would have to be continued. As a final test add to a portion of the solution an excess of ammonia, and if no *blue* coloration appears the solution is free of copper. The electrodes are disconnected from the battery and withdrawn from the solution. The cathode is washed and a few drops of alcohol on the copper deposition are ignited When cold the cathode is weighed, the difference between this and the original weight of the foil being the weight of the copper contained in the ore or in the compound treated.

If w = weight of copper so obtained;
W = weight of ore treated;
p = per cent of copper in ore;

then $$p=\frac{100w}{W}.$$

For a number n of tests, which are made simultaneously, the number of one-gallon cells should be $n+1$, all test-electrodes and cell-electrodes to be connected in series.

Test for Detection of Traces of Copper.[1]—To one drop of a dilute solution, supposed to contain copper, on a watch-glass, add one drop of concentrated hydrobromic acid. Let the solution evaporate slowly to one-half its bulk by placing the watch-glass in a warm place, and a distinct rose color will appear when only $\frac{1}{10}$ milligramme is present in the drop of solution. If more copper is present the mixture becomes at once dark brown or violet. No other metal, except iron when in considerable quantity, interferes with this test.

Examination of Copper in Ores.

Dr. Steinbeck's Process.

Weigh 5 grammes of the pulverized ore, which, when high in sulphur and bitumen, is subjected to a preliminary roasting. The roasted or unroasted ore, as the case may be, is put into a flask, and 40 to 50 c.c. of crude hydrochloric acid, sp gr. 1.16, are poured over it, to which, after a little while, is added 6 c.c. or less of nitric acid, sp gr. 1.2, diluted with its own bulk of water. The mixture is digested on a sand-bath for one hour and boiled for about fifteen minutes.

The solution is filtered into a beaker of about 400 c.c. capacity, in which a pure zinc rod of about 50 grammes and a piece of stout platinum foil fastened to the zinc has been introduced previously. The precipitation of copper begins immediately from the warm concentrated solution, and is complete in from one-half to three-quarters of an hour. The excess of zinc is then loosened from the platinum foil and is removed. The liquid is carefully decanted from the partially floating precipitate of copper and the spongy metallic mass, partially adherent to the platinum foil, is washed by repeated decantations with fresh water. For copper ores containing less than 6 per cent of copper, which is judged by the bulk of the precipitated metal, 8 c.c of the normal nitric acid (acid of 1.2 sp. gr. diluted with its own bulk of water) and for ore over 6 per cent, 16 c.c. of normal nitric acid are added to the precipitate, and by the aid of moderate heat the copper is dissolved After cooling, and just before titration with cyanid of potassium takes place, 10 c.c. of normal solution of ammonia (1 volume

[1] William Crooke's, "Select Methods in Chemical Analysis."

liquid ammonia sp. gr. 0.93, and 2 volumes of distilled water) are added to the solution

In the case where a double quantity, 16 c.c., of normal nitric acid has been used, the copper solution is diluted to 100 c.c and divided into two portions of 50 c.c., to each of which 10 c.c. of normal ammonia solution is added. Lead oxid, which may be suspended in the now deep-blue solution, does not interfere with the process. Cyanid of potassium solution, of a strength that each cubic centimetre indicates 0.005 gramme of copper, is now added from a measuring-burette until the blue color of the solution has disappeared.

Each cubic centimetre of cyanid of potassium solution employed indicates 0.1 per cent of copper in the original 5 grammes of ore tested.

37. METALLURGY OF SILVER.

Process of double lixiviation of silver ores by solutions of hyposulphite of soda and of sulphate of copper **E. H. Russell.**

With the exception of ores with a high percentage of lead or copper, which are more profitably treated by smelting, all silver ores raw or roasted can be treated by lixiviation with advantage.

Silver ores suitable for concentration and roasting or for treatment raw are preferably prepared by dry crushing to a size passing screens from 8 to 30 meshes per lineal inch as extreme limits for roll crushing.

The concentration is preferably to be done by the dry system, so that the concentrate shall immediately be suitable for chloridizing roasting. Avoid wetting down roasted ore while red hot.

Ores may be treated raw or roasted.

Raw ores containing native silver, silver sulphurets, antimonial and arsenical sulphurets.

Roasted ores are distinguished into:

Acid ores, when the first wash-water shows an acid reaction;

Alkaline ores, when it shows an alkaline reaction;

Arsenial alkaline ores, when an unusual amount of arsenates is present.

Solutions.—Stock or ordinary solution consists generally in a solution in water of 1¼ to 1½ per cent sodium hyposulphite. The concentration may in exceptional cases be as low as 0.7

per cent or as high as 3 per cent, but exceeds very rarely 2 per cent

The volume of stock solution per ton of ore may vary between 70 and 200 cubic feet of solution and may in exceptional cases be even lower.

The loss of sodium hyposulphite in lixiviation of acid ores is from 3 to 7 lbs. and in alkaline ores from 1½ to 4 lbs. per ton of ore

This loss is compensated for partly by addition and partly by the composition of the following:

Extra Solution.—This solution being subject to alteration by exposure to air is made whenever needed.

Standard extra solution should contain 1 part of copper sulphate to 2¼ parts of sodium hyposulphite. Therefore, to 100 litres of solution containing 2 25 kilogrammes of sodium hyposulphite, $Na_2S_2O_3+5(H_2O)$, 1 kilogramme of copper sulphate, $CuSO_4+5(H_2O)$, is added.

For raw, acid, and arsenical alkaline ores the weighed quantity of copper sulphate varies between 0 6 and 1 2 per cent and for alkaline ores between 0.1 and 0.33 per cent of the weight of the solution.

The volume of standard extra solution to fill the interstices between the grains of one ton of ore is, for raw ore, 6½ to 9 cubic feet; for acid and arsenical alkaline ores, 10 to 14 cubic feet, just sufficient to saturate the ore, the volume varying according to fineness and specific gravity.

For alkaline ore the volume of extra solution is four to six times the volume to saturate the ore, or to just fill the interstices between the pulverized particles of the ore with liquid.

A standard extra solution containing a little free sulphuric acid is the most permanent, and may be heated to 50° C. = 122° F. with safety

It should not be prepared with alkaline or caustic sodium hyposulphite solution (containing sodium carbonate or caustic soda).

The extra solution which contains double the quantity or 4.5 parts of hyposulphite of soda for 1 part of copper sulphid is most permanent when neutral and may be heated above 50° C.

It is employed for the treatment of ores containing caustic lime.

Precipitating Solutions for Lead.—A solution of pure *sodium carbonate*, Na_2CO_3, is used for the precipitation of lead salts as carbonate of lead In practice about 650 grammes of sodium carbonate are used to precipitate 1 kilogramme of lead.

With proper precaution the amount of lead dissolved should not exceed 2.3 kilogrammes per ton of ore treated.

37a. SILVER, GOLD, AND COPPER.

These metals are precipitated as sulphids from their solutions as hyposulphite double salts, by means of a sodium-sulphid solution.

Preparation of Sodium Sulphid.—Dissolve caustic soda in its own weight of water in an iron tank, filling it one-quarter. Raise the heat when solution has taken place from 80° to 100° C. and add gradually for 100 parts of caustic soda, 66 parts of pulverized sulphur. The mass will soon foam up to two or three times its former volume, and the temperature will rise to about 145° C. The reaction and complete dissolution of sulphur is finished in three or four minutes

As the sodium sulphid so prepared solidifies on cooling, it should be immediately cast into cake-molds for preservation, or dissolved in hyposulphite stock solution and transferred to the storage-tank.

The highest precipitation, 2.3 grammes of silver for 1 gramme of caustic soda, is obtained when 3 litres of solution contain 1.67 kilogrammes of sodium sulphid, and the lowest precipitation of 1.56 grammes of silver for 1 gramme of caustic soda, when 10 liters of sodium-sulphid solution contain 1.67 kilogrammes of sodium sulphid or 1 kilogramme of commercial caustic soda, NaHO, employed in the manufacture of the sulphid.

37b. Test of Silver Solution after Precipitation of Lead with Sodium Carbonate.—Take a sample of the clear solution from the lead-precipitating tank into a test-tube and add a few drops of sodium-phosphate solution. The production of a precipitate would indicate the presence of more lead in the solution, which should be stirred up with a little more carbonate, and, when finally found to be free of lead, should be left to completely settle for about thirty minutes, and then be decanted in the silver-precipitating tank.

Test for Precipitation of Silver, Gold, and Copper.—In adding the sodium sulphid the silver solution should be well stirred, and the stirring continued some time after the precipitation is considered to be complete

Add to a sample of the clear solution in a test-tube gradually a small quantity of sodium sulphid, being careful not to add it in excess When yet a slight precipitate should be produced, the operation is considered to be ended Over-precipitation should be avoided

In from one to four hours the silver sulphids will have sufficiently settled to decant the clear solution.

37c. Treatment of Precipitated Sulphids.—1 The precipitated silver sulphid is collected at convenient intervals of time and filtered preferably under great pressure, 150 lbs. per square inch, in a filter-press The resulting silver sulphid cakes are carefully dried in steam-heated drying-chambers, and may be shipped in this condition to smelters

2 The dried silver sulphid may be partially roasted and, with the addition of scrap-iron and borax, melted in a black-lead crucible and cast into bars

3 If copper is present the damp sulphid cakes are dissolved in sulphuric acid, to which sodium nitrate is added By the violent action sulphur is separated in the form of globules, and may again be employed From the remaining solution the silver can be precipitated by metallic copper

4 The dry sulphids, free from lead and composed mainly of silver and copper sulphids, are roasted in a muffle, the evacuation-pipe of which is connected to the submerged lead blowpipe of a closed Roessler convertor, a lead-lined iron tank partially filled with a hot and not too acid solution of copper sulphate, and provided at the top with an escape-pipe.

The dioxid of sulphur gases, evolved by roasting, are drawn from the muffle, and, together with some air through a regulating cock, are forced through the sulphate solution by a steam-injector, the tank being supposed to contain a charge from a previous roasting The operation ends when all the copper oxids in the charge are dissolved. The contents of the convertor are discharged into a lead-lined precipitating-tank, the clear solution is after a little time decanted, the silver residue, washed and collected in a filter-press, is finally melted with borax and cast into bars.

By crystallization sulphate of copper is obtained from the solution and the mother-liquor is returned to the convertor.

37d. Volumetric Determination of Sodium Hyposulphite Solutions with Iodine.

(All ingredients are supposed to be chemically pure.)

Place in a glass-stoppered litre bottle

8.011 grms. of iodine,
7.5 " " potassium iodid,
100 c.c. of distilled water

Bring the iodine and the potassium iodid together in one spot in the bottle and leave in a dark, moderately warm place for twenty-four hours. If all iodine is then not dissolved, add a little more potassium iodid and bring the remaining iodine in contact with it. When all is dissolved, fill the bottle not quite to the mark with distilled water, leaving something for correction, shake and keep the solution in the dark. One cubic centimeter of this solution, when corrected, is equivalent to 0.01 grm. of sodium hyposulphite.

Starch solution: Add 100 parts of boiling distilled water to 1 part of starch mixed with a little cold water. Place in a tall beaker to settle; decant the clear solution, and filter the rest. To this solution salt, NaCl, is added to saturation and the clear solution is kept for use in 3 or 4 ounce bottles.

Instead of salt a little salicylic acid may be added to the starch solution; this is considered preferable and more convenient.

Correction or Titration of Standard Iodine Solution.—Dissolve 1 grm. of c.p. sodium hyposulphite in 100 c.c. of distilled water. To 10 c.c. of this solution add 1 c.c. of starch solution and dilute to 20 c.c. The starch in this solution should turn blue on the addition of 10 c.c. of iodine solution from a measuring-burette. If the coloration appears with less than 10 c.c., then the iodine solution should be made right by dilution with distilled water.

Determination of Sodium Hyposulphite Concentration of neutral or slightly acid stock solutions.—To 10 c.c. of stock solution add 1 c.c. of starch solution; dilute to 50 c.c. with distilled water. Add standard iodine solution from a measuring-burette until the blue coloration of the starch appears. Each 10 c.c. of iodine solution thus added represents 1 per cent of sodium hyposulphite in the stock solution.

Laboratory Lixiviation Tests. — Preliminary remark: The copper solution is made by dissolving 200 grms. $CuSO_4 + 5(H_2O)$ in water and diluting to 1 litre or 1000 c.c., and this copper-sulphate solution is designated by "Cpr" in the methods of lixiviation described below. The abbreviation "Hypo" is used for sodium hyposulphite. The quantity of pulverized ore treated is ½ Assay Ton, or approximately 15 grms., in a glass beaker of over 300 c.c. capacity. Proceed as indicated below.

Roasted Ores.—Omit leaching with water; use Cpr first.

Cold Solution.—1. Add 50 c.c. water and 25 c.c. Cpr.; let stand two hours, then dilute with water to 300 c.c.; add 20 grms. Hypo. and two hours afterward filter and wash.

2. To the ore add 25 c.c. Cpr. diluted in 250 c.c. of water; leave cold for two hours, then add 20 grms. Hypo., and after two hours more filter and wash.

Heated Solutions.—3. Add to the ore 25 c.c. Cpr diluted with 250 c.c. cold water; after one hour add 20 grms. Hypo.; heat to 55° C. = 131° F.; decant, then add to the ore 25 c.c. Cpr. diluted in 250 c.c. cold water. After one hour add 20 grms. Hypo., heat to 55° C. = 131° F., then filter and wash.

Leach with water by adding to the ore about 300 c.c., stirring, and by decanting the clear solution on the filter to which the tailings are subsequently transferred.

4. Leach with cold water; add 25 c.c. Cpr diluted to 300 c.c. with cold water after standing twelve or eighteen hours; add 20 grms. Hypo., and after again standing cold for twelve or eighteen hours, filter and wash on filter with a hot Hypo solution.

5. Leach with hot water; add to about 30 or 40 c.c. residue of wash-water 20 grms. Hypo.; in one hour add 25 c.c. Cpr., diluted to 300 c.c. with cold water; heat to about 55° C. = 131° F.; then filter and wash.

Raw Ores Cold Solutions.—6. Add to the ore 20 grms. Hypo. in 250 c.c. of cold water; after twelve to sixteen hours decant, and add to the ore 25 c.c. Cpr. diluted in 300 c.c. cold water; in from twelve to sixteen hours add 20 grms. Hypo., and after again twelve to sixteen hours filter and wash.

7. Add 25 c.c. Cpr diluted in 100 c.c. cold water, after twelve to sixteen hours dilute to 300 c.c. with cold water, and add 20 grms. Hypo. In from twelve to sixteen hours filter and wash on filter with hot Hypo. solution.

Hot Solutions.—8. Add to the ore 25 c.c. Cpr. and 100 c.c. cold water, after standing one hour cold, add 20 grms Hypo. and 200 c.c cold water, heat to 55° C = 131° F, then filter and wash.

9. Add to the ore 25 c.c Cpr and 250 c.c cold water; in one hour add 20 grms Hypo, heat to 55° C, decant; add 25 c.c. Cpr. and 100 c.c water to the ore and after standing one hour cold, add 20 grms Hypo; then heat, filter, and wash.

38e. Solubility in one Litre of Distilled Water of Caustic Soda, NaHO, Sodium Carbonate, Na_2CO_3, and Sodium Hyposulphite, $Na_2S_2O_3+5(H_2O)$.

Temperature of Water		Number of Grams Dissolved in 1 Litre of Water			Remarks
C., Deg.	F., Deg.	NaHO	Na_2CO_3	$Na_2S_2O_3+5(H_2O)$	
0	32		69.7	497.5	Solvay soda by ammonia process has 98.7 per cent of pure Na_2CO_3
10	50		120 9		
15	59	600			
20	68		217 1	694 4	Caustic soda, best quality, contains 70 to 76 per cent Na_2O
40	104			1041 6	
60	140			1923	
100	212	2100			

Saturated caustic soda solution boils at 215.5° C. = 420° F.

Weight of Silver Ore Pulp, Raw, Roasted and Lixiviated.

Weight of raw ore per cubic foot from.... 75 to 110 lbs.
Weight of roasted ore per cubic foot from... 55 to 90 lbs.
Lixiviating shrinkage of raw ore.......... 10 to 18 per cent
Lixiviating shrinkage of roasted ore ..... 12 to 24 per cent

38. GOLD QUARTZ.

Dry Assay of Gold Quartz.

1 gramme = 15.432 grains.

Triturate finely in an iron mortar and weigh out.

Gold quartz..............	from	40	to	100	grammes
Litharge.................	"	125	"	310	"
Carbonate of soda........	"	85	"	110	"
Charcoal, powdered.......	"	10	"	25	"
Borax, dry...............	"	10	"	20	"

Omit borax, mix on a clean sheet of paper and put in an assay crucible of proper size to be two-thirds filled, cover with the fused,

finely pulverized borax and heat in an ordinary melting-furnace until complete fusion Towards the end raise heat to bright redness, and when a clear liquid slag is obtained, remove immediately from the fire and pour in a button mold. After cooling remove the slag from the lead button obtained by hammering, and isolate the gold and silver from the lead by cupellation.

Prepare the gold and silver alloy obtained for the parting process by adding pure silver or gold to bring the proportion to 2½ of silver for 1 of gold in the alloy Hammer the button flat, anneal, roll it thin enough and reanneal so that it can be bent into a cornet, introduce into a parting flask and boil with 2 or 3 ounces—60 to 90 grammes nitric acid, of 1 26 gravity, thereby dissolving the silver. The gold remains as a spongy mass, which, after careful washing, is weighed.

As the gold so obtained is never absolutely pure and retains generally a small quantity of lead and silver, a number of proof tests, generally three, are made simultaneously with gold of known fineness, and corrections are made in accordance with the results obtained.

Assay of Gold-bearing Pyrites.—1. After reduction to a fine powder, heat in a shallow dish of refractory clay gradually from low to bright redness in a large muffle under constant stirring, until the roasted ore ceases to emit sulphurous acid gases. Weigh out about 100 grammes of roasted ore, 50 grammes dry carbonate of soda, 30 to 50 grammes litharge or red lead, 5 per cent of powdered charcoal or of granulated metallic lead without charcoal; mix, introduce in crucible and cover with about 50 grammes of fused borax Cupel the lead button obtained, and part the silver and gold alloy resulting from cupellation.

2 Heat the powdered raw ore while adding cautiously and gradually nitrate of potassa until the sulphids of iron, lead, antimony, tin, or zinc are oxidized When the mixture is quite melted, add about 16 parts of lead When cool, subject the lead button to cupellation and part the resulting silver and gold alloy.

Scorification. — Powdered gold quartz 5 grammes, granulated metallic lead 15 grammes for rich ore to 25 grammes for poor ore, borax calcined, 5 grammes. Mix the ore and lead, put in a shallow cup of refractory clay, a scorifier, add on top 15 to 20 grammes more of granulated lead, cover with the

borax, put in the muffle, the latter being decidedly hot, close the muffle until the charge is melted, requiring about ten to fifteen minutes. Expose to a current of heated air, thereby converting part of the lead into litharge.

Towards the end of the operation heat for a short time very strongly. The operation is concluded when a small red-hot iron rod dipped in the mixture is on withdrawal covered by a film of fluid scoria, running off clean It is often desirable to add to the liquid mixture about 1.5 grammes of charcoal or anthracite to reduce part of the litharge into metallic lead, which, in sinking through the scoria, carries small particles of suspended gold down. The button, or prill, obtained should weigh from 25 to 30 grammes and should be soft and quite malleable.

Assay Cupellation.—Cupels: Press moistened bone-ash into cup-like blocks of about 15 or 20 mm. diameter and 10 mm. thickness Keep in a dry place for several months

Preliminary Assay.—(1) Weigh ½ gramme of the alloy to be assayed, and if from appearance copper is supposed to be present, wrap the assay piece in 32 times its weight, 16 grammes of finely rolled pure sheet lead and cupel. From the color of the resulting button the proportion of gold and silver can be judged by an experienced assayer.

(2) To ½ gramme of the alloy to be assayed, add 2½ times its weight, or 1.25 grammes, of assay silver. Wrap the two metals in 5 grammes of pure lead foil and cupel The weight of the silver-gold button obtained, subtracted from the weight of the gold and silver originally employed, gives the copper contents of the assay. The button is then flattened and dissolved in two lots of hot nitric acid. The precipitated fine gold, after washing and drying is heated to redness and weighed when cool. From the weight of the silver-gold button the weight of the pure gold plus the 1.25 grammes of the assay silver are subtracted, and the difference gives the weight of silver in the original ½ gramme of assay.

Chip two small pieces from diagonally opposite corners of the gold ingot to be assayed, one from the top and one from the bottom. Flatten on an anvil by hammering. Roll out in thin strips Weigh from ½ to 1 grm., add fine silver if necessary to make the proportion 2½ silver to 1 of gold. If no copper is present add about 30 mgrms. copper and wrap in finely rolled

pure sheet lead of about thirty-two times the weight of the assay pieces thus prepared.

After a number of assays have thus been prepared heat to redness the corresponding number of cupels in a muffle the bottom of which has been previously covered with powdered bone-ash, and place the assays in the cupels, loosely covering the opening with a hot brick until the assays are melted; then enough hot air is admitted to convert the lead into litharge, which is absorbed by the cupels. The operation is terminated after "brightening," or the emission of a brilliant flash of light has taken place. This is immediately preceded by the appearance of iridescent bands of the last thin films of litharge. In order to expel all traces of lead the heat at this moment should be considerably increased for a short time Then the mouth of the muffle is closed and, after slowly cooling, the cupels with the solidified buttons, are withdrawn.

The presence of foreign metals is manifested by the coloring imparted to the cupels and by some characteristic condition of the slag and button obtained, as follows.

Copper: Dark dirty green.

Antimony: Yellowish, covered by slag; cracks the cupel when in large quantities.

Arsenic: Difficult to cupel; freezes the button; scoriæ white or pale yellow.

Iron: Deep red-brown, fine grains.

Chromium: Dark brick-red.

Manganese: Dark-blue tint.

Cobalt Scoriæ dark green; greenish stain.

Nickel: Greenish tint and slag, in which case the silver spreads out in flat irregular layers.

Lead: Lemon, straw- or orange-yellow.

Tin: Hard to melt; acts nearly like antimony; gray scoriæ.

Zinc: Yellow; eats in the cupel and spoils it.

Bismuth: Orange-yellow.

Palladium: Greenish tint; crystalline button.

The button of gold and silver alloy obtained is removed from the cupel, brushed with a stiff brush, flattened on an anvil, and drawn out between rollers thin enough to be rolled between fingers into small cornets, having been annealed between these operations when found necessary.

Lead Necessary for Cupellation of Gold and Copper Alloys.

Fineness of alloy		1000	900	800	700	600	500	400 to 50
	Gold	1000	900	800	700	600	500	400 to 50
	Copper	0	100	200	300	400	500	600 to 950
Parts of lead for 1 part alloy		1	10	16	22	24	28	34

Parting by Nitric Acid.—Introduce the cornets of gold and 2½ silver alloy into parting flasks containing 2 to 3 ounces pure strong nitric acid, 1.26 specific gravity, free from chlorin, sulphuric acid, or sulphurous acid. Boil until the glass flasks have remained for 3 to 5 minutes free of fumes. Pour the acid carefully off and wash the now porous cornets with hot distilled water. Reboil from 15 to 20 minutes in nitric acid of about 1.3 specific gravity, introducing a ball of porous earthenware to moderate the violent ebullition.

After this acid has been poured off fill the flask completely with distilled water, cover with a small crucible of smooth porous clay, invert the two vessels so that the spongy gold cornet falls through the water in the crucible, and withdraw by a dexterous movement the parting flask, avoiding overflow. Decant carefully the water from the crucible, dry thoroughly, and heat to redness. When cold remove with forceps and weigh.

For correction of the results check assays are made with perfectly pure gold, in each case of the same weight as the gold obtained by the assay to be checked. The cornet sponges from these checks or proofs are weighed and the differences from the original weight indicate the corrections to be made in the weight of the cornet sponge obtained from the assay button.

The silver, being all contained in the silver nitrate solution collected, is precipitated as chlorid of silver by the addition of chlorid of sodium in excess.

This precipitate after being washed and put in water acidulated by hydrochloric acid is restored to metallic silver as a dark-gray powder by the introduction of zinc or of iron, preferably the latter.

The metallic precipitate is washed with dilute sulphuric acid and finally with distilled water, dried, and fused in a crucible with a little carbonate of soda or of nitre and cast.

From the weight of the silver bar so obtained subtract the

weight of silver added to the assay and the result will be the weight of pure silver originally contained in the assay.

Parting by Sulphuric Acid.—The alloy should contain silver 2 to 5 parts; copper from 6 to 8 per cent; gold, 1 part to be melted and granulated by pouring in cold water from a height of about 3 ft. One part of granulated alloy is covered with 3.5 parts by weight of sulphuric acid of maximum concentration, 66° B., in a cast-iron vessel, filling about two thirds of its capacity. The acid is kept boiling for two or three hours, during which fresh acid is gradually added, compensating for consumption and evaporation. Hoods over the vessels carry off the fumes through a condenser to the air.

The solution is left to settle and cold acid is added to accelerate the precipitation of the gold, from which the solution is carefully decanted and the gold precipitate thoroughly washed, adding the wash-water to the sulphate solution in the silver precipitating-tank.

The yet hot acid solution of sulphate of silver is run in a wooden tank lined with lead, provided with inclined hinged covers and containing metallic copper shavings, or slabs or ingots of copper covered with cold water. After a violent chemical reaction, the metallic silver is here precipitated as a beautiful silver mass in about twenty-four hours, the silver having been replaced by copper, which remains in solution as sulphate of copper. This, after concentration, is submitted to crystallization, producing crystals of sulphate of copper or blue vitriol.

To the precipitated gold when dry is added a small quantity of fresh acid and the whole transferred to a smaller cast-iron vessel, in which it is submitted to at least five successive boilings each with a small quantity of fresh sulphuric acid. The decanted acid from these boilings is reserved for a fresh quantity of gold and silver alloy to be parted.

The gold precipitate is then thoroughly washed with cold and hot water and, if very fine, pressed into cakes, which are dried in a current of warm air, then melted in a graphite crucible, and if a trial sample shows the metal to be tough it is cast into bars. If the trial sample shows brittleness, which may be due to a minute quantity of lead, then the gold is fluxed with nitre through an "eye" in a cover of bone-ash.

The silver precipitate is also compacted into cakes by

hydraulic pressure, dried in a current of warm air, and melted with nitre only when selenium or tellurium is present. In this case the spongy silver has a dark color, and would produce a brittle metal melted without nitre.

39a. FOREIGN METALS IN GOLD ORES.

Platinum in auriferous gravel. Collect the gold with mercury; boil the remainder in aqua regia, evaporate to dryness, then add some dilute hydrochloric acid, boil, and filter. Add to the filtered solution a strong solution of sal ammoniac. If the precipitate formed has a bright-yellow or reddish-yellow color, platinum is present in the sand.

When only 2 per cent platinum is present in cupellation the button remains flat and its solution in nitric acid is colored straw-yellow. The iridescence is not as bright and lively and is more prolonged, and on solidifying the button remains dull and tarnished.

Dissolve 10 grammes of finely powdered ore in nitric acid not necessarily concentrated. For the detection of

Lead.—Add to a portion of the solution somewhat diluted sulphuric acid. A white precipitate will be insoluble lead sulphate.

Zinc.—Ammonium sulphid with the nitric-acid solution forms insoluble zinc sulphid.

Bismuth.—Water added to a portion of the nitric-acid solution in a small test-tube forms a white precipitate.

Iron as ferrous salt in the nitric-acid ore solution and potassium-ferrocyanid solution form a white precipitate turning blue on exposure to air; with iron as ferric salt and potassium-ferrocyanid solution the result is a precipitate of Prussian blue.

Manganese.—In the nitric-acid solution, ammonium sulphid forms a precipitate of flesh-colored manganese sulphid.

Nickel solution forms precipitates with ammonia colored a deep blue; with potassium ferrocyanid, greenish white; with potassium and sodium carbonate and caustic potash, light green.

Cobalt solution with ammonia forms a blue precipitate soluble in excess with a brown-red color; with potash blue, turning, on heating, violet and red; with potassium ferrocyanid grayish green.

Mercury solution, with caustic potash or soda, forms a yellow precipitate; with hydrogen or ammonium sulphid, black.

The part insoluble in nitric acid after the solution has been decanted is heated, so as to drive out all nitric acid and dilute hydrochloric acid added and reheated. If to some filtered solution hydrogen sulphid is added and the precipitate is soluble in ammonium sulphid, the presence of arsenic, antimony, or tin is indicated.

Arsenic.—Arsenious-acid solution with hydrogen sulphid forms a bright-yellow precipitate soluble in ammonia; with cupric sulphate and some alkali a brilliant yellow-green precipitate soluble in excess of ammonia is obtained.

Antimony in its solutions with metallic zinc or iron is precipitated as black powder; with metallic copper, as a shining metallic film soluble in potassium permanganate solution; with hydrogen sulphid, as powder of orange or brick-red color, soluble in ammonium sulphid.

Tin as stannous-chlorid solution with hydrogen sulphid and ammonium sulphid forms a black-brown precipitate; with terchlorid of gold forms purple of cassius; color brownish purple.

39. ALLOYS OF GOLD.

	Gold, Per Cent	Alloyed Metals, Per Cent	Specific Gravity	Remarks
Green gold	70	Ag 30		
Electrum	80	Ag 20		
Standard gold, British	91.6667	Cu 8.3333	17.157	English gold coins
" U. S. A. and French	90	Cu 10		Gold coins, U. S. A. and Latin union
Hard gold	87.5	Cu 12.5		
Gray gold	80 to 83	Fe 20 to 17		Grayish yellow

For the manufacture of jewelry, alloys of gold and silver and copper are used.

Gold and Tin form alloys of a yellowish gray to a grayish-white color, mostly crystalline and brittle.

Gold and Arsenic alloy with difficulty, but when once combined, the arsenic can only be driven off with intense, prolonged heat, its vapors carrying some gold with them. Very small quantities of arsenic make gold brittle.

Gold and Antimony.—Brittle, and of a grayish, gray or white color.

Gold and Bismuth.—Brittle, pale brownish yellow and greenish yellow. Cupels readily when heated in air.

Gold and Lead.—Brittle, pale yellow to pale gray. In cooling remain molten below the melting-point and solidify suddenly with a bright flash Is employed for cupellation.

Gold and Zinc. Should be melted in closed vessels or part of the zinc will volatilize An alloy 1 part gold, 7 parts zinc, can be completely volatilized 60 parts gold, 1 zinc, very brittle. Gold 17, zinc 1, pale greenish yellow Equal parts very hard, white Gold 1, zinc 2, white, brittle An increase of zinc makes the alloy ductile.

Gold and Cadmium form gray and brittle alloys.

Gold and Iron.—Gold 11, iron 1, pale yellow; ductile; specific gravity, 16.885. Equal parts gold and iron, gray Gold 1, iron 4, white, hard, magnetic; can be tempered.

Gold-cobalt.—Gold 11, cobalt 1, brittle, dull, yellow; specific gravity, 17 112.

Gold-nickel.—Gold 11, nickel 1; brittle, brass-colored; specific gravity, 17.068. Other alloys are said to be ductile, hard, yellowish white, nearly as magnetic as nickel, and take a good polish.

Gold-aluminium.—Alloys below 10 per cent aluminium are pale yellow, with 10 per cent they are of a brilliant white. Gold 78, aluminium 2.2, splendid purple with ruby-colored crystals Alloys with a greater proportion of aluminium become gray in color.

Gold-platinum.—Gold 11, platinum 1; ductile, yellowish white. Equal parts ductile, gold color. Gold 2, platinum 3, gray Gold 1, platinum 2, brittle

Gold-palladium.—Alloys in all proportions Gold 4, palladium 1; ductile, hard, white Equal parts, hard, ductile, gray; specific gravity, 11.079.

Gold-osmium or Iridium.—No alloys appear to be formed. Irid-osmium separates and sinks to the bottom as black grains in the melted gold.

Gold-molybdenum.—Gold 2, molybdenum 1; brittle, black.

Gold-tungsten.—Alloys yellow, fusible with difficulty

Gold-potassium or Sodium.—Heated together with exclusion of air form alloys which are decomposed by water Gold 10, potassium 90, when thrown on water takes fire, leaving gold as black powder

Gold-mercury or Gold Amalgam.—Mercury and gold unite in all proportions. It is considered that a number of amalgams of definite proportion of gold and mercury may be formed, some of which have actually been isolated. The more or less pasty amalgam resulting from the milling of gold ore is considered to be a dissolution in mercury of one or more gold amalgams of definite proportion.

The free mercury of amalgams collected from amalgamating plates, from amalgamating wells, and from amalgamations, and other sources in the mills after being thoroughly washed and cleaned in a muller is squeezed through close strong canvas bags, through buckskins or chamois leather under water, leaving a hard, dry gold amalgam behind. The mercury squeezed out may retain between 0.5 and 0.7 parts of gold in 1000 parts, while the dry amalgam remaining in the bags will retain from 200 to 300 parts of gold and more per 1000 parts of amalgam.

The amalgam is formed into balls of from 30 to 60 ounces in weight and the mercury is distilled off in cast-iron retorts, either of the pot form, containing 250 to 1000 ounces, or of the cylinder form of a capacity above this quantity, both being provided with a proper evacuating-pipe and condensing apparatus.

The heat of the retorts should only be raised to redness for a few minutes, when all the mercury has been distilled off.

After cooling the retort is inverted over a sheet of strong white paper or a pan, to which the spongy gold will easily be delivered, if the inside of the retort before operation has been properly coated with a wash of fire-clay and graphite. When cylindrical retorts are employed the amalgam is put in strong sheet-iron trays also coated inside with the wash of fire-clay and graphite.

40. POTASSIUM CYANID PROCESS.

Gold Extraction from Tailings.

Apparatus.

Preliminary or Intermediate Vats for the purpose of freeing the pulp of the slimy portion produced in stamping. The vat is completely filled with water and the pulp is discharged evenly into it through a distributing apparatus. The slime remains suspended in the water and overflows into a circular gutter at

the circumference of the vat. From 66 to 80 per cent of the crushed ore remains in the vat.

NUMBER, SIZE, AND CAPACITY OF INTERMEDIATE VATS USED IN A NUMBER OF SOUTH AFRICAN WORKS.

Number	Diameter, Feet	Height of Staves, Feet	Pulp Treated per 24 Hours, Tons	Capacity of Each Vat, Cubic Feet
4	20	8	120	2200
2	20	14	70	4080
2	20	8	70	2200
2	20	7	85	1885
6	24	11	330	4520

From these vats the pulp, after being drained, is discharged through openings in the bottom into tanks and conducted to the leaching-vats.

Leaching-vats are from 20 to 40 ft. in diameter and from 8 to 14 ft. high.

The staves are made of selected well-seasoned lumber, 3 to 4 ins thick.

The bottom of deal 3″ to 9″ is grooved, and tongues coated with white lead or with litharge and glycerin are inserted.

The hoops are made of round iron from ¾″ to 1¼″ diameter, tightened with nuts at connecting pieces. The bottom is supported on wooden beams about 6″×9″, about 18″ apart which rest on bed-plates 1½″×11″, laid on stone foundation walls about 6 to 7 ft. high.

Filter.—Strips of wood 1½″×4″, with notches ¾″×3″ at intervals at the under side, are fastened to the bottom 12″ apart by wooden pins. On top of these are laid crosswise slats 1″ square and 1″ apart. Around the circumference ½″ from the staves a 1″ square strip forms a border. This is covered with cocoanut matting and burlap held in place around the circumference by a ½″ rope driven in the space between the staves and the border. The matting is overlaid by slats 1″×3″, laid 6″ apart for protection from shoveling.

To the space below the filter a pipe is connected with branches, provided with iron cocks, leading to the precipitating-boxes or to tanks containing the different solutions.

Solution Tanks.—There are generally three in number, 1 for strong, 1 for weak solutions, and one for alkaline wash.

They are about 20 ft. diameter and from 7 to 14 feet in height.

Precipitation-boxes are rectangular in form, 15 to 24 feet long, about 3 ft high, and 3 to 4 feet wide, made perfectly tight, of board 1½″ to 2″ thick.

Four such boxes are generally employed; they are housed together with pumps, machinery, furnaces, etc., in an extractor house.

Some are for the passage of strong and some for weak solutions.

The precipitation-boxes are divided into compartments by double partitions so that the liquid flows downward between these partitions and upward in the compartments, the boxes having the necessary fall for this purpose.

All the compartments in a box except the first and the last one contain removable trays of wire screen, ⅛″ mesh, fastened to wooden frames, and filled with filiform zinc shavings, the bottom of each tray being about 4″ from the bottom of the box.

Through the first compartment the solution enters and deposits any fine slime which it may contain. From the last compartment the exhausted solution is conducted by pipes to a pump or tank.

The precipitation box is generally covered by a strong wire netting secured by lock and key.

Operation of the Process.—1. The pulp in the leaching-tank is covered with a 0.15 per cent solntion of potassium cyanid in which is also dissolved about 4 ounces of caustic soda per ton of solution. The pumping will occupy about 3 to 5 hours. A quiet contact of 1 hour is followed by leaching and draining for 8 hours or more. During leaching the pulp is always kept well covered.

2. This is followed without intermission by leaching with a 0.3 to 0.5 per cent solution of KCy, potassium cyanid (strong solution), for from 8 to 18 hours or more. After draining, or from the time when only a very small stream issues from the vat, the pulp should be left exposed to atmospheric air for about 4 hours

3 Then a 0 15 per cent potassic cyanid solution is run on and kept circulating for from 12 to 50 hours. After draining of this weak solution.

4. Wash-water is run through the pulp for about 8 to 24 hours.

Quantity of Solution.

1. Alkaline wash	about	7 to 8	per cent	of	the	pulp	treated
2 Strong solution	"	50 to 55	"	"	"	"	"
3 Weak "	"	15 to 20	"	"	"	"	"
4. Wash-water	"	8 to 10	"	"	"	"	"

Cyanid of potassium ¾ to 1¼ lbs per ton of tailings treated.

In some cases where considerable acids are contained in the tailings, produced by long exposure to air, each truckful of tailings is mixed with the proper quantity of powdered caustic lime before it is dumped in the leaching-vat. The first washing is then performed with water, with which the leveled tailings are covered, and thus left quiet for fully 1 hour, when the leaching may start, the acids being by this time fully neutralized

While the caustic wash is draining off, the slimy film formed on top is broken up with shovels, and a strong potassium cyanid solution of 0.25 to 0 3 per cent strength containing about ¾ lb of cyanid of potassium per ton of tailings treated, is turned on and leached through for several hours.

After draining and exposure to air, this is followed by leaching with a weak solution of from 0.08 to 0.15 per cent of potassic cyanid, which is continued until the pulp is apparently exhausted, when the final operation of washing with water and draining dry is performed.

Precipitation of the Gold.—From the leaching-vat a pipe conducts the now gold-bearing solution into one of the 4 precipitating-boxes, two of which are connected with strong solution storage, one with the weak solution storage, and the last one with the caustic wash storage-tank

Part of the dissolved gold is deposited as a thin film on the zinc shavings in the compartments of the precipitating-box, but the greatest part is separated as a very fine slimy precipitate, which falls ultimately to the bottom of the compartment.

As the zinc shavings are consumed by this process, they are replenished as required

Zinc consumed, 0.4 to 0.5 lb per ton of tailings, 4½ ounces zinc per ounce of gold extracted.

Monthly Clean Up.—Clean water is run in the precipitating-box to remove the cyanid solution. Starting with the last

compartment, the zinc trays are lifted up and moved up and down for the removal of any adhering gold particles and then lifted out, the zinc removed, and the frames carefully washed brushed in the water of the compartments, and placed on racks above so as to drip in the box.

The water from the compartments is pumped out to within about 2 feet of the slime at the bottom, into a settling-tank. The gold slime is collected into one corner of each compartment, and after settling for a while, the remaining liquid is pumped as much as possible from the compartments in the settling-tank.

The gold slimes are now scooped into an enameled iron bucket from which they are discharged and washed through a fine sieve (900-mesh) into the clean-up tank. After the gold has settled, the clear water is siphoned or pumped from the latter. By removing a plug at the bottom of the tank the gold slime is run into a filter-press, or on a calico or linen filter, and the remainder of the water filtered out. When the gold slimes can be handled with a scoop, they are dried on an iron plate or in an iron pot, and subsequently roasted.

For roasting nitre (nitrate of potassa) from 3 to 10 per cent of the precipitate may be added before drying it in the shape of a solution The temperature should not be raised beyond a dull-red heat, and stirring should be performed carefully, so as to avoid the production of dust.

Smelting Mixture.

	Clean	With Zinc	Very Sandy
Precipitate	30 lbs.	30 lbs.	30 lbs.
Bicarbonate of soda	15 "	15 "	20 "
Borax	8 "	12 "	10 "
Sand	5 "	5 "	—
Fluor spar	—	—	2 "

The well-mixed charge is put in portions into a plumbago crucible No. 35, each successive portion being added when the preceding one is well melted down. When every part of the charge is fused to perfect liquidity, which requires a rather higher heat than for melting gold alone and a very good furnace, the mass is transferred to conical moulds. After the mass is cool the slag is hammered from the metal

Several pieces of bullion, obtained in this manner from one clean up, are remelted together with borax at a low heat and are cast in one ingot, avoiding liquation by quick solidification.

The slags are crushed and the metal which they contain is recovered by panning or cradling

The bullion obtained ranges in fineness between 600 and 800. It is contaminated with silver, zinc, and occasionally lead and carbon

U. S. Patents Covering the Process.—J S. McArthur, R. W. Forrest, and W. Forrest, No 403,202, May 14, 1889. Process of obtaining gold and silver from ores.

J S MacArthur, R W Forrest, and W. Forrest, No. 418,137, Dec 24, 1889 Process of separating gold and silver from ores.

J C Montgomerie, No 532,895 January 22, 1895. Process of extracting gold and silver from ores.

40a. ELECTROLYTIC GOLD EXTRACTION from Potassium Cyanid Solutions.—*Siemens and Halske.*

The tailings of the leaching-vat are treated with about 7 per cent of alkaline wash followed by leaching with about 50 to 55 per cent of a potassic cyanid solution of 0.05 to 0.08 per cent strength and about 15 per cent of a potassic cyanid solution of 0 01 per cent strength and afterward washed with water

The precipitation takes place in four electrolytic precipitation-boxes, each 20 ft long, 8 ft wide, and 4 ft deep The anodes are made of iron plates ⅛ in thick, of a length occupying the whole width of the box, about 3 ft deep, so placed in the boxes that they form regular compartments of about 3 ins. width, through which the solution flows alternately up and down. They are surrounded by canvas forming electrolytic porous cells. The cathodes are made of thin sheet lead 2 ft. by 3 ft weighing about 1 lb. each sheet, three of them being stretched side by side on a light wooden frame, hung between the iron plates about 1½ ins. apart, each box containing 87 such frames

The iron anodes are connected to a copper rod at one side, and the lead cathodes to a similar rod at the other side of the precipitating-box; the two copper rods being connected by conductors to the + (positive) and − (negative) posts of a dynamo, furnishing a current of about 0 06 amperes per square foot of cathode surface at 7 volts, requiring about one horsepower per ton solution treated per hour. At the "clean up," which generally takes place once a month, the cathode frames are lifted out one after the other, the sheets of lead now covered

by a hard deposit of gold are removed, and immediately replaced by new sheets of lead in the solution.

The gold-covered lead sheets of one "clean up" are then melted together, and the gold is extracted from the lead alloy by cupellation

Iron is dissolved about ⅓ lb. per ton of solution treated.

Consumption of potassium cyanid in this process is about ¼ lb. per ton of tailings treated.

Extraction of fine gold about 70 per cent

40b. Tests and Preparation of Solutions.

Determination of Caustic Lime to neutralize acidity in tailings —Put 1 klgm of the tailings in an enameled or glazed vessel, cover with 2 or 3 litres of water, stir, and leave quiet for a while Test with blue litmus paper, which will turn red if acid is present Add gradually from a weighed quantity (50 grms) of powdered quicklime until the red color of the litmus paper is again converted into blue Weigh the remaining quicklime, which by subtraction from the original quantity weighed gives the quantity of caustic lime which has to be added to each kilogramme of the tailings to be treated.

Strength of Potassium Cyanid. KCy Solution.

1. Dissolve in 1 litre of distilled water 13.03 grms. of chemically pure nitrate of silver

Add this solution gradually from a burette, divided into centimetre cubes and fractions, to 10 cubic centimetres (c.c) of the potassium cyanid solution to be tested, until a white precipitate begins to be perceptible.

Each cubic centimetre of silver nitrate added indicates the presence of 0.1 per cent of potassium cyanid, KCy, in the solution tested.

2 Of a strong solution from a dissolving-tank dilute 10 c.c. with distilled water to 100 c.c In this case each cubic centimetre of the standard nitrate of silver solution added to 10 c.c. of this diluted-test solution indicates 1 per cent of potassium cyanid in the solution

3 For very weak solution dilute 10 c.c. of the standard silver-nitrate solution to 100 c c Each cubic centimetre of this last solution added to 10 c c of a potassium-cyanid solution to be tested indicates the presence of 0.01 per cent of KCy.

Preparation of Potassium-cyanid Solutions.—The commercial article contains about 80 to 90 per cent of pure potassium cyanid

Lumps of the salt are placed on a filter made of a coarse sieve covered with jute, and the water solution is pumped over it, and kept constantly circulating. The insoluble impurities remain on the filter They are chiefly composed of carbide of iron, and are, after washing with water, thrown away.

This constitutes a very strong storage solution from which the stock solutions for leaching are prepared

If p=percentage of KCy in the desired stock solution;
n=percentage of KCy in the existing stock solution;
m=percentage of KCy in the storage solution;
Q=quantity of existing stock solution;
q=quantity to be added from the storage solution to the stock solution in order to bring it to the required per cent, p;

then $q=Q\left(\frac{p-n}{m-p}\right)$.

40c. Gold in Potassium-Cyanid Solutions.

1. Buchanan's method: To 195 c c of the gold potassium-cyanid solution in a half-litre glass flask add a few drops of potassic-chromate solution, and of a 5 per cent silver-nitrate solution, until the reddish tinge of the test indicates the completion of the reaction. From 10 to 20 grammes of fine zinc shavings are now thoroughly mixed with the solution, and from 2 to 3 c.c of 10 per cent sulphuric acid added In about ten minutes add excess of acid to dissolve the remaining zinc Filter the precipitate, wash, dry, incinerate on a roasting-dish in a muffle, and cupel with some lead.

2 Cross's method: To a litre of potassium-cyanid-gold solution add silver nitrate in excess, filter the quickly-settling precipitate on a large filter After drying, put the precipitate in a covered crucible with flux and say about 30 grammes of litharge, melt and cupel the lead button obtained, and part the gold from the silver If the potassium-cyanid solution is strong, add acid to neutralize the excess of potassium cyanid, avoiding thereby a too large consumption of nitrate of silver

Test of Ore for Gold Extraction by Potassium-cyanid Solutions.—1. A portion of about 200 grammes of a sample, crushed

so as to pass a 30-mesh sieve, is shaken for about twenty minutes with 100 c.c. of a 0 5 per cent potassium-cyanid solution in a glass-stoppered bottle.

If, after a test of a filtered-off portion of the solution, it is found to have 0.4 per cent strength, the consumption having been 0.1 per cent potassium cyanid of the solution, or 0.05 per cent of the ore, the latter being double the weight of the solution in the test, the ore does not require preliminary treatment before leaching with potassium-cyanid solution.

2. If from the test of the filtered solution it is found that the consumption has been excessive, a fresh portion of 200 grms. of the crushed ore is mixed with water in a stoppered bottle, and a solution of 10 grms. of commercial caustic soda in 1 litre of water is gradually added from a graduated burette, and the mixture shaken until a drop of the liquid from a glass rod dipped in it will turn red litmus paper slightly blue. Each cubic centimetre of the caustic soda solution added will indicate $\frac{1}{10}=0.1$ lb. of the same quality of the soda to be needed to neutralize the cyanid-destroying substances in one ton of 2000 lbs. of the ore.

3. If this test should show that more than 3 lbs. of caustic soda should be needed per ton of ore, then another sample of 200 grms of ore should be water-washed before adding the caustic-soda solution, and the neutralizing proportion for this washed ore determined. If this should show a reduction of the quantity of caustic soda required per ton of ore, then the ore should be washed before treatment with the caustic-soda solution.

Cyanicid is the technical term employed in this process to express the quantity in pounds of caustic soda needed to neutralize the potassium-cyanid-destroying substances in one ton of 2000 lbs of ore.

4 Copper in the ore is detected by adding to the filtered solution of No. 1 nitric acid, evaporating to dryness, redissolving in a little more nitric acid, diluting with water and precipitating with ammonia, the presence of copper being indicated by the blue coloration of the liquid.

5 The time necessary to expose the ore to the action of the potassium-cyanid solution and the proportion of gold extracted are determined by weighing out a number of samples, each of about 200 grms., subjecting them to the preliminary treat-

ment with alkali wash or water indicated by the above tests, then adding 100 c c of 0 5 per cent potassium-cyanid solution to each sample in a convenient vessel, which may be a lamp-chimney stoppered at one end by an india-rubber stopper, provided with a short glass tubing, closed by a short piece of rubber tubing and a burette clip The stopper is covered on the inside with a filtering material which may be filtering-paper, a piece of sponge, or asbestos fibre

One sample is exposed to the action of the potassic-cyanid solution for one day, the second for two days, the third for three days, etc

The solutions are successively drawn off and each tested for its contents of potassium cyanid; the samples of ores so treated are successively washed and each sample is assayed for the gold left in it.

A sample of original ore, not subjected to any solution treatment, should previously be assayed to determine the gold contents in the ore.

A comparison of the assay after treatment, and the assay before treatment, will then determine the percentage of gold extraction by the process employed

Detection of Arsenic and Antimony.—Put some pure zinc in a small flask containing distilled water acidulated with pure sulphuric acid, close its neck with cotton wool, and hold over it a sheet of moist tissue paper freshly covered with a solution of bichlorid of mercury If only hydrogen is evolved no change takes place in the color of the paper, if arsenic or any of its compounds is placed in the flask a lemon-yellow spot appears which gradually becomes pale yellowish brown. Antimony compounds introduced in the flask produce a brownish-gray spot

40d. Detection of Traces of Gold in Minerals.—A finely powdered sample of the mineral is mixed with an alcoholic iodine solution well shaken and allowed to subside After a while a piece of Swedish filter-paper is dipped in the liquid, dried, and burnt to ash The presence of gold is indicated by the purple color of the ash, which will be white if no gold is present

Pyrites are roasted and subjected towards the end to a bright-red heat, so as to decompose the ferruginous sulphate.

41. ELECTROLYSIS.

Electric Insulation.

(Substances approximately ranged in order of their relative power of insulation for electricity.)

1. Ebonite	11. Mica	21. Lime	31. Dry wood
2 Shellac	12 Silk	22. Dry gases	32. Alcohol, ether
3 Caoutchouc	13 Wool	23 Dry steam	33 Rain-water
4 Gutta percha	14 Hair	24. Phosphorus	34. Spring water
5 Amber	15 Feathers	25. Fatty oils	35 Sea water
6 Resin	16 Dry paper	26 Dry metallic oxid	36 Graphite
7 Sulphur	17 Leather		37 Brittle metals
8 Wax	18. Porcelain	27 Straw	38 Ductile metals, lead
9 Agate	19 Camphor	28 Ice at 0° C	
10. Glass	20 Chalk	29 Paper	39 Platinum
		30 Marble	40 Silver, copper

Resistance of Liquids, Copper = 1 at 0° C = 32° F.

Nitric acid at 55° Fah = 12.8° C.	976,000
Sulphuric acid diluted to $\frac{1}{11}$ at 68° F = 20° C	1,032,000
Chlorid of sodium saturated solution 56° F = 13.3° C.	2,903,838
Sulphate of zinc saturated solution	15,861,267
Sulphate of copper at 18° F. = 9° C.	16,885,320
Distilled water at 59° F = 15° C	6,754,208,000

If the resistance of silver is 1, the resistance of gutta percha of the same diameter and length = 850×10^{18}

Relative Conducting Powers for Electricity of Pure Metals.

Dr. Mathiessen.

Silver..........	100	Cobalt.......	17.2	Antimony .	4.6.
Copper.........	99.9	Iron........ .	16 8	Mercury.. ..	1.6
Gold.	77.9	Nickel.......	13 1	Bismuth	1 2
Zinc.	29	Tin ...	12 4	Graphite .	0 069
Cadmium.......	23 7	Thallium......	9.2	Gas coke. .	0 038
Palladium....	18 4	Lead.	8 3	Bunsen coke..	0.025
Platinum.......	18	Arsenic.... .	4 8		

Electrolytical Nomenclature.

M Faraday

Electrolysis.—The decomposition of a liquid by an electrical current.

Electrolyte.—The liquid or solution which is acted upon by electricity

Electrodes.—The conductors immersed in the liquid or electrolyte.

Anode, or Positive Pole.—The conductor through which the electric current enters

Cathode, or Negative Pole.—The conductor by which the electric current leaves.

Ions.—The elementary substances which are set free by the action of the current on the liquid.

Anions, or Electro-negative Substances.—The elementary substances, which appear at the anode or positive pole: Metalloids, pe oxids, acids

Cations, or Electro-positive Substances.—Those which are evolved at the cathode or negative pole: Metals, alkalies, and bases.

Reguline Metal.—Metals having qualities similar to castings of the same substances.

Generalities.

The quality and purity of the deposited metal is determined by the composition of the electrolyte Metals in the reguline state are deposited only from a few liquids, and thick layers have been obtainable so far only from 3 or 4 electrolytes.

Copper, antimony, and silver are most easily obtainable in thick layers.

Gold, platinum, nickel, zinc, tin, cadmium, and lead are usually only deposited in thin films or layers or in rough nodules and crystalline forms Most of the remaining metals have so far only been obtained as a dark powder

Some electrolytic liquids have to be heated, and some continually stirred while in operation.

Antimony, and, in a less degree, iron and nickel, while being deposited are liable to crack and curl up.

Iron forms an extremely hard deposit, and nickel becomes sometimes so hard that it cannot be burnished

Copper and even gold, when electro-deposited, are remarkably hard

Electro-deposited metals are more or less crystalline and porous They cannot be used for tight vessels without annealing and they do not protect surfaces from oxidation.

Seams can not be closed or edges joined by electro-deposition.

Electrolytic Solutions for Nickel-plating.

Material	Klgm. or Litre	Preparation	Authority
Sulphate of nickel and ammonium.	1	Dissolve to saturation; filter after cooling	Adams Gaiffe Elmore
Distilled water.	10		
Sulphate of nickel and ammonium. . .	0 4	Dissolve separately in part of hot water Pour carbonate into nickel solution until neutralized	Roseleur
Carbonate of ammonium.	0 3		
Distilled water. .	10		
Sulphate of suboxid of nickel	2	Heat to boiling-point, then neutralize with strong ammonia until test-papers show only faint acid reaction	Weiss
Chlorid of ammonium ..	1		
Citric acid . . .	0 1		
Distilled water.	50		
Nitrate of suboxid of nickel	4	Dissolve the nickel salt in ammonia: the sodium sulphite in water; mix	Boden
Solution of caustic ammonia. . . .	4		
Acid sulphite of sodium..	50		
Distilled water. . .	150		
Sulphate of nickel and ammonium.	0 08	Dissolve in the boiling water; cool, and filter	Pésille
Distilled water .	1		

Preparation for Nickel-plating.

1. Scouring bath for rough castings:

   Sulphuric acid. . . . . 0.25 litre
   Water, hot. . . . . 10.00 litres

   Potash bath:

   Potash. . . . . 1 kilogramme }
   Water. . . . . 10 litres } Use hot.

2. Cyanid bath:

   Potassic cyanid. 0.5 klgrm.
   Water. . . . . 10.0 litres

3. Whiting bath:

	Litres	
Sulphuric acid.	2	Add to the nitric acid in earthenware the sulphuric acid, then the soot, and finally the salt Avoid the fumes of the hot mixture.
Nitric acid.	1	
Soot calcined by volume. . .	0.1	
Sodium chlorid by volume..	0.1	

4. Hydrochloric acid bath for iron or steel:

Hydrochloric acid.	1 litre	Substitute for potassic cyanid in the treatment of iron.
Water.	5 "	

5. Dipping copper bath:

Sulphuric acid........	0.1	klgrm.	Dissolve the sulphate in hot water, add the acid.
Sulphate of copper....	0.1	"	
Distilled water.......	10	litres	

6. Coppering bath for zinc:

Acetate of copper crystallized.......	0.25	klgrms.
Carbonate of soda..................	0.2	"
Bisulphid of soda crystals...........	0.2	"
Potassic cyanid....................	0.3	"
Water distilled.	10	litres

Keep boiling when in use.

Anodes for nickel-plating when soluble should be made of rolled bars of pure nickel; when insoluble, platinum is everlasting, carbon anodes disintegrate in the bath and produce trouble.

Electrolytic Solution for Silver-plating and Solutions for Preparation of Articles.

Material	Klgms or Litres	Preparation and Use	Authority
Potassic cyanid....... Silver cyanid. .... Distilled water..........	0.5 0.25 10	Dissolve pure granulated silver in hot nitric acid (40°), evaporate, dissolve the silver nitrate in 10 or 15 times its weight of water; add hydrocyanic acid until precipitate ceases to be formed. Collect the silver cyanid on a filter	Roseleur
		Cleansing before plating	
Potash or caustic soda. .. Water.	1 10	Use boiling hot	
		Pickling	
Sulphuric acid.......... Water.	1 10	Rinse well after using this bath.	
		Scouring	
1. Nitric acid (36°). ..... Sodic chlorid Lampblack. .... 2 Nitric acid (36°). . .. Sulphuric acid (66°).... Sodic chlorid.........	10 0.2 0.2 6 0.2 0.2	Immerse in 1 Rinse in running water, then quickly immerse in 2 and rinse in pure water several times	
		Amalgamation	
Dioxid of mercury....... Water. . ... Sulphuric acid, pure......	0.1 10	Put the oxid in the water; add acid until complete solution. Immerse for a few seconds and rinse	
		Oxidation for antique silver:	
Sulphate of copper........ Potassic nitrate......... Ammonia hydrochlorate, dissolved in acetic acid.	2 1 2	The silver-plated object is brushed with a camel's-hair brush and a solution of platinum chlorid in sulphuric ether, alcohol, or cold water, then covered with the sulphate of copper solution	

Maximum electromotive force 2 to 3 volts.
Maximum current per square metre of cathode. 50 amperes.

Solutions for Gold-plating and Preparation of Object to be Plated.

Substances	Klgms. or Litres	Preparation	Authority
1. Gold to be dissolved in aq. regia (2 hydrochloric acid, 1 nitric acid) Potassic cyanid, concentrated Distilled water........	0 0023 1 1	The gold chlorid after evaporation to dryness is dissolved in 30 c c distilled water, potassic cyanid added, stirring with glass rod Lixiviate precipitate, redissolve in potassic cyanid, dilute to 1 1 litre	Watt
2. Gold chlorid from gold Ammonia........ Potassic cyanid....... Distilled water........	0 0023 1 1	Dissolve in distilled water 30 c c precipitate with ammonia, dissolve the precipitate with potassic cyanid solution, dilute to 1.1 litre	Watt
3. Gold, pure......... Potassic cyanid, pure.. Water distilled........	0 01 0 2 10	Transform the gold into chlorid with aqua regia; dissolve in 2 litres of water. Dissolve potassic cyanid in 8 litres, mix the two solutions, boil for 30 minutes; use cold, maintain the solution by adding potassic cyanid and gold chlorid in about equal parts	Roseleur
Hot process 50° to 80° C.. 4. Sodic phosphate .... Sodic bisulphite ... Potassic cyanid.... Gold (transform to chlorid). ..... Water distilled.......	 0 6 0 1 0 1 0 01 10	Dissolve the sodic phosphate in eight litres of hot water, and the gold chlorid cold in 1 litre of water; mix gradually. Dissolve the potassic cyanid and sodic bisulphite in 1 litre of water; mix the two solutions	Roseleur

Solutions 3 and 4 contain 1 grm. of gold per litre. The deposition can take place at the rate of 0.25 or ¼ grm. per hour and per square decimeter.

Green gold is obtained in a bath containing from 5 to 6 grms. of gold per litre, a plate of silver being used as soluble anode, until the green tint of the deposit is obtained, when the silver anode is replaced by one of green gold.

Red gold: Use a soluble copper anode and substitute when the proper color is obtained an alloy of gold of the color required.

Maximum electromotive force, 1 volt.

Maximum current per square metre of cathode, 10 amperes

Preliminary Treatment of Articles to be Gilded.—Substantially the same as for silver. Copper and its alloys can be gilded directly without amalgamation. Silver may also be gilded directly, but is often covered with a preliminary film of copper.

Final Treatment of Gild Articles for Coloration.

Substances	Parts by Weight	Preparation	
1. Alum	3	Make into a paste. Brush the objects with this paste, heat on an iron plate until nearly black, then wash in water	
Potassic nitrate	6		
Sulphate of zinc	3		
Sodic chlorid	3		
2. Sulphate of copper	3	Pulverize the solids and mix; then add the acid, stirring the mass. Dip the articles and heat on a sheet of copper until they begin to blacken. Cool, then dip in sulphuric acid, and wash	
Verdigris	7		
Ammonic hydrochlorate	6		
Potassic nitrate	6		
Acetic acid	31		

Gilding by Immersion.

Substances	Klgms or Litres	Preparation	Authority
Potassic pyrophosphate	0.800	After proper preparation, immerse the articles to be gilded under constant stirring for a few seconds	Roseleur
Hydrocyanic acid, 1 to 8 water	0.008		
Auric perchlorid	0.020		
Distilled water	10		

Coppering.

Substances	Klgms or Litre	Preparation and Use	Authority
For Coppering zinc		The copper sulphate is dissolved in 1 litre of hot water. When cold, stirring well, while adding ammonia until the precipitate at first forming is redissolved. Then add concentrated solution of potassic cyanid until the blue color has completely disappeared. Used at 50° to 55° C.	Watt
Sulphate of copper	0.230		
Ammonia (density 0.880)			
Potassic cyanid			
Distilled water	1		
Cupric acetate	0.35-0.45	The first column is for large pieces, the second for small pieces	Roseleur
Sodic sulphite	0.3-0.1		
Potassic cyanid	0.5-0.7		
Ammonia	0.2-0.15		
Water distilled	25		
Coppering iron:			
1. Cupric sulphate	1	Dissolve separately in the quantity of water, and mix the two solutions 1 and 2: used for coppering rollers; for calico-printing	Schlumberger
Sodic sulphate	2		
Sodic carbonate	4		
Water	16		
2. Cyanid of potassium	3		
Water	12		

Deposition of Iron.

Substances	Klgms. or Litres	Preparation	Authority
Best quality iron wire. . . Hydrochloric acid Ammonic chlorid.	0 060 0.055	Dissolve the iron in the acid with excess of iron and the application of heat; near the end add the ammonic chlorid; dilute, add a little glycerin	

Deposition of Tin.

Substances	Klgms. or Litres	Preparation	Authority
a. Stannous chlorid. . . Water distilled. . . *b* Caustic potash. . . . . Water. . . . *c*. Sodic pyrophosphate. . Water . . . . *d*. Potassic cyanid. . . .	0 19 0 5 1 5 10 1 5 3 1 5	Prepare each solution separately. Pour *b* into *a*, stirring with a glass rod; add *d*, then finally add *c*, keep the solution agitated	Fearn

Preparation of Potassium and Silver Cyanids.

Substances	Klgms. or Litres	Preparation	Authority
Cyanid of Potassium. *a*. Ferrocyanid of Potassium, dry. . . . . . *b*. Carbonate of potash, dry.	 0.9 0.3	Dry *a* on a clean sheet-iron plate over a slow fire, stirring to prevent caking, mix with *b*, also perfectly dry. Put the mixture in a red-hot cast-iron crucible; when fused stir with a clean iron rod for 15 minutes, or until the liquid on cooling on the iron rod appears white or grayish, if a new crucible is used. Remove, let settle, and pour the clear liquid in an iron vessel; scrape the sediment from the crucible while yet hot	Liebig
Cyanid of Silver. *a*. Silver, pure granulated *b*. Nitric acid, concentrated. . . . *c*. Water, distilled. . . *d*. Cyanid of potassium	 0.030 0 120 0.030	Mix *b* and *c*, and dissolve *a* with heat. Dilute with water, add *d* until precipitation ceases. After settling, decant. Wash the precipitate by adding water and decanting 3 or 4 times.	

Preparation of Silver Solution by Electrolysis.—For every litre of water contained in a tank dissolve 10 grms. of cyanid

of potassium. In porous cups in this solution, and containing the same solution, place sheets of iron or copper serving as cathodes. In the solution in the tank place sheets of silver as anodes. Connect the latter to the positive and the cathodes in the porous cups to the negative pole of a battery.

Gold Solution by Electrolysis.—Dissolve for each litre of water 30 grms of cyanid of potassium and heat to 65° C.= 150° F Place in the tank containing this solution porous cups filled with the same solution. In the porous cups put sheet-iron or sheet-copper cathodes, and in the solution in the tank sheet gold anodes; connect the cathodes to the zinc, and the anodes to the copper, of a battery.

Solutions for gilding are made to contain from 4 to 9 grms. of gold per litre.

42. GALVANIC OR ELECTROCHEMICAL BATTERIES.

ARRANGEMENT OF NAMES OF CHEMICAL ELEMENTS, SO THAT THE FOLLOWING SHALL BE CONSIDERED AS ELECTRO-NEGATIVE TO THE PRECEDING

Positive.

1 Hydrogen	9. Iron	17. Carbon	25. Sulphur
2. Potassium	10. Nickel	18. Platinum	26. Iodin
3 Sodium	11 Cobalt	19 Iridium	27 Bromin
4 Magnesium	12 Lead	20. Rhodium	28 Chlorin
5 Aluminium	13 Copper	21 Nitrogen	29. Oxygen
6 Zinc	14 Silver	22. Antimony	30. Fluorin
7 Cadmium	15 Palladium	23. Tellurium	
8 Tin	16 Gold	24. Selenium	

Negative.

Tables of Galvanic Cells.

The main types of such cells and the principal modifications thereof are arranged in tabular form. Each number constitutes a single cell which, for single-fluid cells, is composed of the positive and negative elements and the necessary exciting and conducting solution, all contained generally in a glass, or in some other insulating jar In double-fluid cells one of the elements is placed in a porous cell in a solution different from the surrounding solution containing the other element, both being contained in an insulating jar. Batteries consisting in troughs containing a multiplicity of pairs of elements are not represented in the tables.

The chemical symbols are used as abbreviations to designate the substances without reference to the atomic weight implied therein in chemical formulas: Ag=silver; C=carbon; Cu=copper; Fe=iron; Hg=mercury; Mg=magnesium; Mn=manganese; Pb=lead; Pt=platinum; Zn=zinc; AZn=amalgamated zinc; AgPt=platinized silver; CPt=platinized carbon; MnO_2=manganese peroxid; PbO_2=lead dioxid Acids: H_2SO_4=sulphuric; HCl=chlorhydric; HNO_3=nitric; CrO_3=chromic acid, etc Bases: HKO=caustic potash; HNaO=caustic soda, etc Chlorids: NH_4Cl=ammonium chlorid, chlorhydrate of ammonia, or sal ammoniac; CaCl=calcium chlorid; NaCl=sodium chlorid, common kitchen salt; MgCl=magnesium chlorid; ZnCl=zinc chlorid, etc Various salts: $CuSO_4$=copper sulphate; $ZnSO_4$=zinc sulphate; $MgSO_4$=magnesium sulphate; KNO_3=potassium nitrate, saltpetre; $NaNO_3$=sodium nitrate; $KClO_3$=potassium chlorate; $K_2Cr_2O_7$=potassium bichromate; $Na_2Cr_2O_7$=sodium bichromate; $KMnO_4$=potassium permanganate; $NaMnO_4$=sodium permanganate; $NaH_5C_4O_6$=sodium bitartrate; Na_2SiO_3=sodium silicate; $Fe_23(SO_4)$=iron sulphate; Hg_2SO_4=mercury sulphate

Amalgamate zinc: Scour the zinc with a solution of wash-soda; rinse in clean water; apply a drop of mercury to the surface of the zinc and spread the same by rubbing; repeat the application of mercury until the surface acquires a mirror-like lustre.

Remarks: In 4 and 5 the AgPt and CPt, or platinized silver and platinized carbon, are the result of immersing the plates in a solution of platinum chlorid or Pt ammonium chlorid and, after drying, subjecting them to sufficient heat to leave metallic platinum in a finely divided state disseminated over the surfaces of the plates, with the object of providing a great number of fine points for the disengagement of the hydrogen With the same object the C velvo in 6 is composed of a carbon plate covered by carbonized cotton velvet, the nape of the velvet forming the outside surface.

In 11, Hg, the mercury, covers the bottom of the containing glass jar; the paste of chemicals is placed over it, and the zinc superposes the paste. An insulated conducting-wire leads out of the jar from the mercury at the bottom.

In 12, the surfaces of the lead plate, Pb, are covered with lead dioxid, PbO_2.

Single-fluid Cells.

Reference Number	Poles: Positive: Substance	Poles: Positive: Condition	Poles: Negative: Substance	Poles: Negative: Condition	Exciting Solution: Chemical Compound	Exciting Solution: Parts: Chemical	Exciting Solution: Parts: Water	R, Ohms	E, Volts	Authority	Year
1	Cu	1 plate	Zn	1 plate	H_2SO_4	1.0	10			Volta	1800
2	Cu	2 plates	Zn	1 plate	H_2SO_4	1.0	10			Wolaston	1815
3	Cu	2 plates	AZn	1 plate	H_2SO_4	1.0	10			Kemp	1828
4	AgPt	1 plate	AZn	2 plates	H_2SO_4	1.0	12		0.47	Smee	1836
5	CPt	2 plates	AZn	1 plate	H_2SO_4	1.0	12		0.66	Walker	1859
6	C Velvo	1 plate	AZn	2 plates	H_2SO_4	1.0	6–12	0.07	0.5	Barnett	1894
7	C	2 plates	AZn	1 plate	$K_2Cr_2O_7$	1.0	10	0.07	1.9	Poggendorf	1839
					H_2SO_4	0.5				Grenet	1841
					$NaSO_4$	1.4	40				
8	C	1 plate	AZn	1 plate	$K_2Cr_2O_7$	2.95	to				
					H_2SO_4	6.86	60				
9	C	1 plate	AZn	1 plate	$Na_2Cr_2O_7$	3	10				
					$NaNO_3$	3					
10	C	2 plates	AZn	1 plate	$K_2Cr_2O_7$	3	20		1 9	Fermoy	1890
					HCl	3					
11	Hg	bottom	Zn	top	$ZnSO_4$	Paste			1.44	Clarke	
					Hg_2SO_4					Rayleigh	
12	$Pb+PbO_2$	2 plates	AZn	1 plate	H_2SO_4	1.0	8	0.02	2.36	Reynier	1884
13	Lithanode	1 plate	AZn	1 plate	H_2SO_4	1.0	4.5		2.35	Kingsland	
14	$C+CMnO_2$	1 plate	AZn	1 plate	NH_4Cl	1.0	6			De Larue	
15	C,ZnO		AZn	1 plate	$ZnCl_2$			1	1	Pabst	1887
16	Ag, AgCl	1 plate	AZn	1 plate	NaCl	1.0	40		1.3	De Larue	
17	Cu, CuO	1 plate	Zn	1 plate	HKO				0 98	Lalande	1882
or	Fe, CuO	1 plate	Zn	1 plate	HKO						
18	Cu	1 plate	Zn	1 plate	HNaO			0.06	0.8	Leitner	
19	$C+C, MnO_2$	1 rod	AZn	cylinder	NH_4Cl	1	5.5	1.5	1.48	Leclanché	1868
20	$C+C, MnO_2$	cylinder	(AZn	rod)	NH_4Cl	1	5.5			Lacombe	1894

In 13, lithanode is prepared by forming a stiff paste with a mixture of dioxid of lead, PbO_2 sulphate of ammonium, NH_4SO_4, and glycerin, pressing this paste into plates and baking them dry

In 14, 19, 20, the carbon surfaces are surrounded by a mixture of equal parts of carbon, in grains, and of manganese peroxid, also in grains, contained in a canvas bag, or in a porous, unglazed porcelain cell. In 20, the carbon has the form of a cylindrical ring surrounding the porous cell containing the zinc; the annular space between the carbon ring and the porous cell is filled with the compacted mixture.

In 15, 16, 17, the metal surfaces are covered with the oxids or chlorid indicated.

Double Fluid Cells.—The two fluids may be separated by a porous cell, generally of baked unglazed porcelain clay, or a carbon electrode may be formed into a porous cup, or the two fluids may be separated by gravity, the lighter floating on top of the heavier solution.

In the table, parentheses, ( ), indicate that the electrode and solution, the symbols of which are contained therein, are in the porous cup; the same symbols italicized indicate that the said electrode and solution are superposed to the other electrode and solution in gravity cells. Abbreviations and symbols have the same meaning as in the tables for single fluid cells. The letter s in the columns of parts signifies that the solution should be kept saturated, that, therefore, in such cases provision should be made so that there is always a certain amount of the respective chemical salt present for solution.

In 5, $NaC_4H_5O_5$ = sodium bitartrate. In 6, the porous cell was made of parchment paper In 11, Na_2SiO_3 = sodium silicate.

In 14, two additional porous cells of small size were put in the jar; one containing crystals of potassium chromate $K_2Cr_2O_7$, the other containing sulphuric acid H_2SO_4.

In 15, the cylindrical zinc concave surface is parafined so that only the convex surface opposite the carbon is active.

In 16, the 4 carbon plates are suspended from the cover of the jar.

In cells like 7, 8, 9, 10, 12, 17 where nitric acid is used as the oxidizing agent, nitrous acid fumes are emitted, when the battery is in action; the connections of the conducting

Double-fluid Cells.

Reference Number	Positive Pole					Negative Pole					R. Ohms	E. Volts	Authority	Year
	Substance	Form	Solution, Parts			Substance	Form	Solution, Parts						
			Salt or Acid		Water			Salt or Acid		Water				
1	Cu	cylinder	$CuSO_4$	s		(AZn	rod	H_2SO_4	1	12)		1.079	Daniel	1836
2	Cu	cir. plate	$CuSO_4$	s		*AZn*	*rod*	H_2SO_4	1	12			W Thomson	1839
3	{ Cu or Pb }	cylinder	$CuSO_4$	s		*AZn*	*ring*	$MgSO_4$					Meidinger	
4	Cu	cylinder	$CuSO_4$	s		*AZn*	*rod*	$ZnSO_4$					Calland	
5	Cu	cylinder	$CuSO_4$	s		*AZn*	*ring*	$NaC_4H_5O_6$					Eisenlohr	
6	Cu	2 plates	$CuSO_4$	s		(AZn	1 plate	$HNaO$	1	3)	0 075	1.4	Reynier	1880
7	(Pt	1 plate	HNO_3	—	0)	AZn	2 plates	H_2SO_4	1	12		1 96	Grove	1839
8	C	cylinder	HNO_3	—	0	(AZn	1 plate	H_2SO_4	1	12)	0 08	1 96	Bunson	1840
9	(C	1 rod	HNO_3		0)	AZn	cylinder	H_2SO_4	1	12	0 08	1 96	Archereau	1842
10	C	cylinder	HNO_3+HCl			(AZn	rod	H_2SO_4	1	13)	0 05	2	D'Arsonval	1879
11	C	cylinder	{ HSO_4+ $Na_2Cr_2O_7+$ $NaMnO_4$ }			(Mg	1 plate	Na_2SiO_3	s	)		3 5		
12	C	cylinder	{ $K_2Cr_2O_7$ $+HCl$	2 5 2 }	20	AZn	1 plate	$ZnCl$	1	20			Dale	1881
13	C	cyl. or pl.	{ $K_2Cr_2O_7$ H_2SO_4	12 25 }	100	(Cu	1 plate	H_2SO_4	1	4)			Thomson	
14	C	cyl. or pl.	$K_2Cr_2O_7$			(AZn	1 plate	$KHSO_4$		)		1.87	Baudet	1885
15	C	cylinder	{ $Na_2Cr_2O_7+$ $NaCl$ }	s		(AZn	cylinder	H_2SO_4	1	10)			Howard	1886
16	*C*	*4 plates*	$K_2Cr_2O_7$	1	16	AZn	cir. grate	H_2SO_4					Kousmine	1890
17	(Ag	1 plate	HNO_3+HCl		)	AZn	cylinder	H_2SO_4	1	12			Rouillon	1867
18	(C	plate	Fe_23SO_4	s	)	AZn	cylinder	NH_4Cl	s		1	1.8	Willrants	1882
19	C	rod	$HgSO_4$	pa	ste	AZn	cylinder	H_2SO_4	0.1	100		1.52	Davy	

wire with the electrode should therefore be carefully made and well covered with several coats of acid-proof varnish.

The top of carbon electrodes should be electrolytically covered with a film of copper and the conducting connection carefully soldered to this plating, and all metallic parts liable to be exposed to corroding fumes well varnished Applicable to cells with sal ammoniac solution and those using hydrochloric acid.

Dry Cells.

Ref. No	Carbon Rod, Depolarizing Paste			Zinc Vessel, Exciting Paste			R., Ohms	E., Volts	Authority or Inventor	Yr.
	Ingredients	Pts.	Agglomerator	Ingredients	Pts	Agglomerator				
1	MnO_2 C $ZnSO_4$ NH_4Cl	1 8 0 5 0 5	water glycerin	$CaSO_4$ NH_4Cl ZnCl	3 0 5 -1	water	0 5	1 5	Gassner	1886
2	MnO_2 C		water	NH_4Cl CaCl ZnCl		gelatin	0 15	1 56	Hellessen	1890
3	MnO_2 C NH_4Cl		glycerin water	NH_4Cl MgCl $CaSO_4$	2 1 6 5	glycerin water flour	0 1 to 0 75	1 5	Brittish	
4	MnO_2 C			MgCl MgO NH_4Cl CaCl		glycerin and water			Mehner	1889

Remarks.—In the dry cells represented in the foregoing table the zinc electrode is in the form of the vessel containing all the other parts of the cell. For insulation this zinc vessel is covered with thick strong paper or with a good quality of thin paste-board, well varnished over the whole outside surfaces Bottom and sides of the zinc vessel inside are lined with a thickness of about ¼ inch or more of the exciting paste indicated in the table, leaving about one inch on top bare. The carbon rod should extend sufficiently above the top of the zinc vessel for convenient attachment of the conducting wire; this rod is placed centrally in the vessel, on a thickness of depolarizing paste at the bottom, and the space between the vessels exciting lining and the carbon is filled with the compacted depolarizing paste, to the same height as the exciting paste. On top of the pastes a thin layer of loose mineral wool, or asbestos, is placed, on which two small and short pieces of glass tubing are set up diametrically opposite each other,

so as to form holes for the escape of gases. By filling the space to the top of the zinc vessel with molten pitch or asphaltum, the cell is sealed; connection of the zinc vessel with a conducting wire by soldering having previously been made.

In 2, two concentric zinc vessels are provided, the annular space between them being filled with mineral wool, asbestos, or sawdust; a number of circumferential holes are made just above the pastes in the inner vessel, and similar holes near the bottom of the outer vessel for the escape of gases which may be evolved. No openings are in the sealing pitch in this case.

In 1 and 3, $CaSO_4$ = calcium sulphate, or plaster of Paris, acts in reality as an agglomerator, in which capacity gelatinous hydrate of silica has also been used.

Dry cells with pastes requiring more or less chemical operations and manipulation have been omitted from the table, as such complications are not proper to be put into tabular form.

43. IRON AND STEEL.

IRON ORES.

Chemical Compositions and Physical Properties.

Mineralogical Name	Chemical Formula of Pure Ore	Iron per Cent	Water, H_2O, Carbonic Acid, CO_2, Sulphur, S	Hardness	Sp. Gr.	Color of Powder
Hematite ...	Fe_2O_3	70		6	5 5	Red-brown
Limnite . . .	$Fe_2O_33(H_2O)$	52 34	25 32	5 5	4	Yellowish brown
Xanthosiderite	$Fe_2O_32(H_2O)$	57 14	18 37	2 5	4	Ochre yellow
Limonite. ..	$2(Fe_2O_3)(3H_2O)$	60 87	14 43	5 5	4 4	Yellowish brown
Gothite. .	$Fe_2O_3H_2O$	62 9	10 11	5 5	4 4	Brownish ochre, yellow
Turgite.....	$2(Fe_2O_3)H_2O$	66 28	5 33	6	3 7	Reddish
Siderite. ...	$FeOCO_2$	48 27	CO_2 37 93	4 5	3 9	White, yellow, and brown
Magnetite. ..	Fe_3O_4	72 41	—	6	5	Black
Pyrite.......	FeS_2	46.7	S 53.3			Yellow

Cast Iron.

Average Chemical Composition.

(Per Cent.)

Trade Name of Pig Iron	Iron	Manganese	Copper	Carbon, Combined
Foundry........	93–94	0–0 99	0–trace	0 to 0 56
Bessemer.......	83–92	1 25	——	1 33–1 17
Scotch pig.....	90 5–90 7	1 58–1 62	0 07–0 1	0 28–0 46

Trade Name of Pig Iron	Carbon, Graphitic	Silicon	Phosphorus	Sulphur
Foundry........	1 86–4 81	1 18–3	0 03–0 12	0 –01
Bessemer......	2.88–4	2 5 –2 7	0 07–0 09	trace
Scotch pig....	3 –3 4	2 9 –3 5	0 75–0 98	0 02–0 04

Note.—Foundry is pig iron for casting parts of machinery; Bessemer is of proper composition for conversion into steel.

Scotch pig is used as a mixture for very thin castings like stove-plate.

Chemical Composition of Iron and Steel and Electric Conductivity.

Designation	Total Carbon, Per Cent	Manganese	Sulphur	Silicon	Phosphorus	Cr, Chromium, Tg, Tungsten	Specific Resistance 10^{-6} Ohms
Bessemer mild steel	0 015	0 2	0.3	—	0 04		10·5
Whitworth mild steel							
Annealed....	0 09	0.153	0 016	—	0 042		10.8
"	0 890	0 165	0 005	0 081	0 019		15.59
Oil-hardened.	0 890	"	"	"	"		16.95
Manganese steel:							
Forged........	0.674	4 73	0 023	0 608	0 078		53 68
Annealed.....	"	"	"	"	"		39.28
Oil-hardened....	"	"	"	"	"		55.56
Chrome steel:							
Forged.....	0.687	0 028	0 020	0 134	0.043	Cr, 1.195	17.91
Annealed.......	"	"	"	"	"	"	18 49
Oil-hardened.....	"	"	"	"	"	"	30.35
Tungsten steel:							
Forged..........	1 357	0.036	—	0 043	0 047	Tg, 4.649	22 49
Annealed........	"	"	"	"	"	"	22 50
Oil-hardened.....	"	"	"	"	"	"	22.74
Wrought iron......	—	—	—	—	—	—	13 78
Cast iron, gray......	3.45	0.173	0·042	2.04	0.151	{ C, graphitic 2.05	114.0
Spiegeleisen........	4.51	7.97	trace	0 502	0.128	—	105·2

Commercial Malleable or Weld Iron.

(Impurities in average samples in per cent.)

	Carbon, Combined	Carbon, Graphitic	Silicon	Sulphur	Phosphorus	Manganese	Copper	Cobalt	Nickel	Slag
A	0 033	0 009	0 073	0 004	0 078	0 005	0.046	0 034	0 037	0 974
B	0 429	0 024	0 105	trace	0 065	0 006	0 008	trace	0 011	0 326
C	0 057	0 009	0 020	0 001	0 075	0 009	0 008	0 020	0 023	1 214
D	0 069	0 010	0 159	0 004	0 161	0 026	0 079	0 027	0 034	0 470
E	0 025	0 008	182	0 009	0 252	0 033	0 081	0 037	0 057	0 848
F	0 043	0 008	0 303	0.003	0 213	0 007	0 011	0 013	0 008	1 230

A, very ductile, little tenacity; B, very strong, hard to weld; C, best for general purposes; F, weak, brittle, unsatisfactory

Tool Steels.

Temper	Carbon, Per Cent	Remarks
Razor . . .	1 5	Very sensitive in heating and to hammering
Saw file . . .	1 375	Cannot support heat above cherry red
Tools . .	1 25	For metal work, as turning, planing, milling
Spindle. . .	1 125	Mill-picks, taps, screw dies, etc.
Chisel.	1	Cold chisels, drills, for blasting, etc.
Set.	0 875	Sets, drifts, all tools for heavy blows of hammers
Die.	0 75	Dies, tools to resist great pressure
Rails	0 3–0 4	Rails, structural steel works, etc.
Machine. . .	0 1–0 01	Machine parts, shafting, boiler-plate, etc.

Components of Iron in Special Steels.

Designation.	Carbon, Combined	Carbon, Graphitic	Silicon	Sulphur	Phosphorus	Manganese	Copper	Chromium
Dr. Dudley's rail.	0.3	--	0 04	--	0 1*m*	0 4		
Chrome steel, A.	0.627	0.012	0.154	trace	0 007	0 05	0 008	1 044
" " B	0.439	0.015	0.136	0 001	0 019	0 023	–	0.912
" " C. . .	0 461	—	0.166	trace	0 020	0 027	trace	0 612

Note.—*m* in the column of phosphorus means maximum allowable.

The chrome steels were made in Brooklyn under the direction of the patentee, Mr. Baur.

43a. Cast Iron.

Chemical Composition of Cast Iron and Consequent Physical Properties.—Cast iron consists of a combination of iron with various but small proportions of carbon, silicon, sulphur, phosphorus, manganese, and in some rare cases chromium, nickel, aluminium, etc.

Carbon in cast iron exists under two conditions: As combined carbon producing hardness in the iron, or as graphitic carbon producing softness.

The maximum total amount of carbon in cast iron may reach 4.5 per cent, which may all be in the graphitic state, producing soft gray iron of a coarse crystalline and granular fracture.

The higher the proportion of combined carbon the harder the iron and the closer the surface of fracture

Combined carbon can be produced by quick cooling or chilling; it is promoted by the presence of sulphur, and depends on the amount of silicon present The lowest combined carbon is found in iron having from 4 to 7 per cent of silicon

Graphitic Carbon in iron in the melted state is indicated by a lively vibration of different colors on the surface of the molten iron, and in cooling from a high temperature to a lower one a scum or "kish" will form and float away, and often cover everything near with thin flakes of shining plumbago

Silicon may be absorbed by iron in as high a proportion as 20 per cent. Iron containing over 5 per cent is generally designated by the name of **silicon iron or ferrosilicon.**

An increase of silicon from 0.1 to 3 per cent produces an increase in softness and fluidity of the iron. Beyond 3 per cent the hardness increases again Cast iron of about 2 per cent of silicon has the maximum tenacity

If from 3 to 5 per cent of silicon is present in cast iron all the combined carbon is converted into graphitic carbon.

Castings, except for electrical purposes should never contain more than 3 per cent of silicon, as over 4 per cent becomes very injurious to the strength and soundness of the iron

Metal high in silicon when in a melted state will show a smooth surface with a quiet dull, sparkless appearance. Iron high in free carbon or in silicon when running from the cupola throws off very few sparks.

Ferrosilicon, mixed with scrap, burnt, and hard iron, can be advantageously used for a cheap kind of work Eighty per cent of scrap and 4 per cent of ferrosilicon in a mixture will make good machinable iron of not less than 1" in thickness.

Sulphur ranges in good No 1 foundry pig from 0.01 to 0.03 per cent; for lower grades from 0.03 to 0.05 and in some white iron it may reach 0.08 per cent.

An increase in the proportion of sulphur produces an increase in the tenacity of the iron by producing an increase in the combined carbon and therefore in hardness, but it also produces an increase in shrinkage and red shortness.

Phosphorus may exist in pig iron in the proportion of a trace to as high as 7 per cent. In foundry iron it varies generally between 0.25 to 1.0 per cent, while for steel-making it should not exceed 0.1 per cent. In castings limited from 0.2 to 0 7 per cent it is rather beneficial for strength and toughness, but beyond 0.7 per cent it is very hurtful It produces fluidity in the molten metal and soundness in the castings.

Manganese varies in proportion from a trace to 3 per cent in pig iron; the average in good gray iron being about 0 5 per cent, but may be as high as 2 per cent in pig iron, and produce good castings.

Manganese promotes graphitic carbon and eliminates to a certain extent sulphur, rectifying the deleterious effects of the latter.

In a hot furnace the manganese combines with the pig iron; in a dull furnace it combines partly with the slag. In remelting in a very hot, well fluxed cupola, the manganese is partly eliminated.

Manganese may to a certain extent produce hardness in cast iron when present in the pig iron, but when about 0.15 per cent of powdered *ferromanganese* is added and stirred in a ladle full of molten hard cast iron, it has for effect to soften the latter by converting about one half of the combined carbon into graphite, to increase its strength 30 to 40 per cent, and to decrease the shrinkage 20 to 30 per cent.

Ferromanganese is a combination of iron and manganese in various proportions; between 30 and 80 per cent of manganese and a few per cent of carbon constitute *ferromanganese*

Iron containing from 15 to 30 per cent of manganese is known as *spiegeleisen*.

Chromium has been found in pig iron from trace to the proportion of 0.12 per cent A metal alloy of chromium and iron has been produced containing 84 per cent of chromium, called **ferrochrome.** Chromium when present in pig iron promotes the absorption of carbon up to 12 per cent by the iron.

Copper nickel, aluminium, titanium, calcium magnesium, sodium, potassium, arsenic, and other substances have occasion-

ally been found to be present in iron in very minute quantities, but the influence of their presence seems not to have been specially investigated and so far has not been considered of any practical importance.

In remelting cast iron the amount or percentage of silicon will decrease about 10 per cent, while the proportion of sulphur will be double, and in some cases over three times as much as in the original pig iron.

A decrease in the percentage of manganese is generally accompanied by a decrease in sulphur With proper management in the operation of a cupola, an excess of manganese will be oxidized and carried off with a portion of the sulphur in the slag.

Total carbon may be slightly increased by an excess of fuel and a high temperature, and decreased by little fuel and a low temperature.

Combined carbon may be slightly decreased when silicon is over 4 per cent and sulphur not more than 0.01 per cent. When silicon becomes reduced below 4 per cent and sulphur increased above 0 02 per cent, every remelt will increase the combined carbon until nearly all the carbon is combined and the iron produced has been converted into white iron.

An increase of graphitic carbon is promoted by high silicon, medium phosphorus and manganese, and low sulphur

Phosphorus remains practically stationary by remelting; but all the phosphorus contained in the fuel or flux will generally be found in the iron It should not exceed 0 9 per cent even for very light work.

The larger the proportion of silicon up to about 4 per cent and of phosphorus to .1 per cent and the lower the sulphur and manganese, the higher will be the proportion of graphitic carbon, and therefore the softer the castings. The harder the iron the sooner it melts; hard iron should therefore be melted first in a cupola, when several grades are required from one heat.

High sulphur gives a hard friction-resisting chill, liable, however, to chill-crack; while high manganese promotes a gradual chill, somewhat yielding to strains and less liable to chill-crack from heat; and is therefore in all cases preferable

High carbon, all other component parts remaining the same, will produce deep chill.

Average Chemical Composition of Various Grades of Cast Iron.

Substances Combined with Iron in Per Cent of Cast Iron	Charcoal			Coke or Anthracite			
	Pig Iron	Gun-metal	Chill Roll	Foundry		Bessemer	
				No. 1	No 2	No 1	No. 2
Combined.		1 13	1.38	0.15	0 3	0.35	0.65
Carbon.	3 to 3.5	3 18	3	3 65	3 3	3 85	3 65
Graphitic.		2.05	1 62	3 5	3	3.5	3
Silicon.	0.6 to 2	1 19	0 71	3	2 25	2	1 25
Phosphorus.	0.15 to 0 25	0 408	0 543	0 6	0 5	0 09	0 09
Sulphur.	0 to 0 004	0 055	0 058	0 01	0 02	0 025	0 05
Manganese.	0 4 to 1	0 42	0 39	0 3	0 4	0 5	0.45

Substances Combined with Iron in Per Cent of Cast Iron	Coke or Anthracite				
	Chill Car-Wheel	Machinery		Stove-Plate	Electric Machinery
		Heavy	Light		
Combined.	0.92	0.33	0.43	0 35	0.06
Carbon.	3 47	2.98	2 93	3 3	2.95
Graphitic.	2 55	2.65	2 55	2 95	2 89
Silicon	0 86	1 05	1.83	2 59	3.19
Phosphorus.	0 348	0 543	0 504	0 622	0.89
Sulphur.	0 127	0 11	0 078	0 072	0.075
Manganese	0 49	0 35	0 31	0 37	0 35

Cast iron proper for chill work has the following general proportion of combined substances in per cent: carbon, 3 to 4; silicon, 0 5 to 1 1; phosphorus, 0.2 to 0.7; sulphur, 0.02 to 0.1; manganese, 0 55 to 1.5.

For electric work castings should be very soft, therefore high in silicon. A metal of good magnetic permeability on analysis was found to contain silicon 3.19, sulphur 0.075, phosphorus 0.89, manganese 0 350, carbon, total, 2.95 (combined C. 0.06, graphitic C. 2 89), all in per cent.

If sulphur is reduced to 0.05, the same softness is produced by silicon 2 6.

Depth of Chill in Cast Iron.—(1) The deepest chill is produced if the iron remains in contact with the chill mould until cold.

(2) Hot poured iron produces a deeper chill than dull poured iron.

(3) Difference in grade determines a variation in depth of chill.

(4) The quicker the heat is absorbed the deeper the chill

(5) The chill is deeper in thin than in thick castings.

Mitis Castings.—To cast iron, melted in a crucible in a petroleum furnace, is added 0.05 to 0.1 per cent of aluminium. For the iron obtained, a superior soundness, and a tenacity from 20 to 50 per cent larger than ordinary cast iron, is claimed.

Cupola Charges.—For 50 ton heat in a 66″ cupola.

Bed of Connellsville coal	2000 lb.
First charge of pig iron on bed	8000 lb
Coke charges, regular	450 lb.
Pig iron charges, regular	6000 lb.

Fluxes.—Material: Marble spalls, limestone, dolomite, fluorspar, oyster and clam shells. For extra quality of fuel and clean metal 20 to 30 lbs. of limestone per ton of iron melted.

For fuel as ordinarily used and iron as delivered by furnaces, 40 to 80 lbs. of limestone per ton of iron is necessary.

44. CHEMICAL TESTS.

IRON AND STEEL.

Elimination of Phosphorus from Pig Iron.

1. (J. Lothian Bell.) Pig iron, with 1 to 2 per cent phosphorus, is run in a reverberatory furnace, lined with iron peroxid or iron ore rich in peroxid, and stirred so as to produce a strong action of the peroxid on the molten iron, which is kept at a temperature just sufficient to keep it fluid.

A ton of molten pig containing in 100 parts 1.8 silicon, 1.4 phosphorus, and 3.5 carbon was changed in 10 minutes so as to contain in 100 parts 0.05 to 0.01 phosphorus and 3.3 carbon.

2. (Krupp of Essen.) Pig iron, direct from a blast-furnace, from a cupola or from a reverberatory furnace, is run on a hearth with a bottom made of a mixture of oxid of iron and oxid of manganese at a high temperature. In from 5 to 15 minutes, 5 tons can be purified, the impurities passing in the slag.

Determination of Carbon.—In about 120 c.c of water, dissolve 36 grammes of double chlorid of copper and ammonium.

In this solution, under frequent stirring and the application of gentle heat after a few minutes, dissolve 3 grms. of steel or iron to be tested. Add a few drops of hydrochloric acid if a film of iron oxid forms, in order to dissolve it. Filter in a filter made of a test-tube about 7 5 c long and 1.5 c. inside diameter drawn at its lower end to an opening of about 4 m.m., containing in the contracted lower end some angular pieces of glass superposed by asbestos wool previously well ignited. Before and after using the filter, wash with hot water. Any small quantity of basic chlorid of copper which may separate, is redissolved by the addition of the necessary quantity of the double chlorid solution. The carbon is retained in the asbestos and is converted into carbon dioxid without drying by Ullgreen's process.

(By color of solution, Séraign) Over a water-bath of 80° C., borings of steel in two portions, each 0 2 grm., are dissolved in 20 c.c nitric acid, sp. gr. 1 2

Two other portions of steel of known carbon contents, as 0.60 and 0 62 per cent, are treated similarly, using the solutions as standards. All the solutions are placed in glasses of the same width and brought to the same color by the addition of water. The relative volumes indicate the proportion of carbon.

Sulphur in Steel and Iron.—(Fresenius.) Dissolve the iron or steel in hydrochloric acid; conduct the evolved sulphuretted hydrogen through an alkaline solution of oxid of lead, passing at the same time a current of dry hydrogen through the apparatus in order to prevent oxidation of the sulphid of lead precipitate From the weight of the latter, collected on a filter, the quantity of sulphur is calculated

(Dr. Thos M. Drown.) In a flask of about ½ litre, dissolve 10 grms. of steel borings by adding gradually about 50 c.c. of hydrochloric acid, and pass the hydrogen sulphid evolved through at least 3 successive bottles containing solutions of 5 grms. of permanganate of potassa in 1 litre of distilled water. After complete dissolution or cessation of evolution of gas, draw air through the apparatus for some time, and then pour the contents of the bottles into a beaker, rinsing with water, and dissolving any adhering oxid of manganese with hydrochloric acid The undissolved residue in the flask is treated twice with nitrohydrochloric acid, and each time

evaporated to dryness, redissolved in hydrochloric acid, filtered and the filtrate added to the solution in the beaker. Add now enough hydrochloric acid to completely decompose the permanganate, converting it into a colorless solution. The sulphur has now been converted into sulphuric acid, and is determined by the addition of chlorid of barium, and precipitated as barium sulphate.

Silicon.—In a mixture of 1 part concentrated sulphuric acid and 6 parts of distilled water, dissolve by boiling 1 grm. steel; exclude air; evaporate water completely, rendering thereby silica insoluble. Add a few drops of hydrochloric acid and hot water; filter and wash with hot water acidified with 5 per cent nitric acid.

Ignite with filter and weigh, deducting weight of ashes of filter-paper, obtaining weight of silicic acid.

If d=diameter in centimetre of best Swedish filter-paper then weight of ashes$=0.0001\ d^2$ grm.

Phosphorus in Pig Iron or Steel.—Mix equal volumes of nitric acid, sp. gr. 1.42, and of hydrochloric acid, sp. gr. 1.195, and dissolve in the mixture 5 grms. of steel. Evaporate to dryness and heat until all dark fumes have ceased to escape. Dissolve the dry mass in strong hydrochloric acid, evaporate to remove excess of acid, add hot water and filter silica off. Evaporate filtrate until it is just fluid, cool and then add 4 c.c. of strong nitric acid and increase the bulk with distilled water to 20 c.c. Add in a thin stream, while stirring, 20 c.c. of molybdate of ammonia solution (composed of 100 grms. of molybdate of ammonia, 1000 c.c. of distilled water and 100 c.c. of ammonia sp. gr. 0.88), then add a few drops of ammonia and shake until precipitate of iron disappears. Submit for 1 hour to moderate heat with occasional shaking, so that a precipitate distinctly separates, leaving a clear supernatant solution. If arsenic is present it will precipitate along with phosphorus and give inaccurate results. After settling, pour on a 4″ Swedish filter, wash with warm water so as to concentrate the precipitate at the centre of the filter.

The filtering-paper should be quite white and washed before use with cold water, acidulated with 1 per cent of nitric acid.

Unfold the filter upon another filter, and dry under cover of a large watch glass at from 100° to 140° C. When dry, shake and brush the precipitate from the filter into a pre-

viously weighed porcelain dish and weigh as phosphoric acid, $P_2O_5 3(H_2O) = 2(H_3PO_4)$

Phosphorus in Metals, Determined as Phosphoric Acid.—Prepare a solution by dissolving 25 grms. of molybdate of ammonia in 100 c.c. dilute ammonia, pour this solution under constant stirring or agitation into 500 c.c. of dilute nitric acid (3 volumes strong acid 1 volume water), heat to 50° C. for some time and draw the clear solution off.

The metal is dissolved in nitric acid free from hydrochloric acid, and is freed from arsenic and silicic acids by boiling to dryness, heating until arsenious fumes cease to escape, redissolving in nitric acid, boiling and filtering to free from silica. The filtrate is mixed with an excess of ammonium molybdate solution, boiled for a few minutes and filtered after standing a short while. The precipitate is washed with dilute nitric acid, dissolved in ammonia and precipitated with magnesia mixture as phosphoric acid.

Manganese.—Test in the absence of chlorids:

For a preliminary test, heat the substance to be tested in dilute nitric acid, add a little lead peroxid. If manganese is present its oxidation will impart to the solution the pink color of permanganic acid.

Manganese in Spiegeleisen, Iron or Steel.—(Sergius Kern.) One gramme of the powdered substance is dissolved in 30 c.c. hydrochloric acid and heated for about 30 or 40 minutes.

The liquid is evaporated to one half of its bulk, and water added, and the insoluble matter (silica) filtered through asbestos and well washed.

The filtrate is treated with an excess of potash, precipitating the iron and manganese, which are filtered off, well washed, dried and strongly ignited in air, producing a mixture of sesquioxid of iron and protoperoxid of manganese, Mn_3O_4. These powders are placed in a small hard glass tube, and a current of hydrogen is passed through it, while it is heated to redness. After 15 or 20 minutes the mass assumes a greenish color, consisting of a mass of metallic iron and protoxid of manganese. It is cooled with the hydrogen passing through it, and the cooled tube is introduced into naphtha and emptied, crushing part of the tube while immersed if the mass should not readily separate. The iron is removed by a magnet; the remaining protoxid of manganese is washed, dried, and ignited;

thereby reconverted into protoperoxid, Mn_3O_4, containing 72.05 per cent of metal and weighed.

Volumetric Determination of Manganese in Steel or Pig Iron.—1 Two titrated solutions in distilled water are prepared as follows:

A. Oxalic acid $H_2C_2O_4+2H_2O$ 2.285 grms. in 1 litre of solution, each 1 c.c. containing the equivalent of 1 milligram of Mn in MnO_2, in accordance with the equation:

$$H_2C_2O_4+MnO_2+H_2SO_4=MnSO_4+2CO_2+2H_2O.$$

B. Potassium permanganate, $KMnO_4$, 1.148 grms in 1 litre of solution, 1 c.c being the equivalent of 1 c.c. of the above oxalic acid solution in accordance with the equation:

$$5H_2C_2O_4+2KMnO_4+3H_2SO_4=K_2SO_4+2MnSO_4+10CO_2+8H_2O.$$

This solution may be made so that 2 or 3 c.c. are necessary to saturate 1 c.c. of oxalic-acid solution. The potassium-permanganate solution should be prepared in two portions, one too concentrated and the other too dilute; both should be boiled and then left for 2 days to precipitate, and from the two portions a mixture of the proper strength should be made.

In about 40 c.c. of concentrated nitric acid 1 grm. of steel or pig iron is dissolved with heat. In the case of pig iron, after solution filter through asbestos, washing with concentrated nitric acid for the removal of silica and carbon. Keep the steel solution or the pig-iron filtrate boiling, while gradually and cautiously adding 1 to 2 grms of potassium chlorate, pulverized. This precipitates the manganese as dioxid, MnO_2. Filter through asbestos with the aid of the filter-pumps, and wash well with water.

The precipitate, with the asbestos in the filtering funnel, is now blown in the beaker, in which the manganese has been precipitated, washing the funnel with water, and adding a moderate excess of the titrated oxalic acid over what is supposed to be needed to neutralize the MnO_2 contained in the beaker.

If a sample of 1 grm. of iron or steel which has been treated in this manner is estimated to contain in the vicinity of 1 per cent of manganese, then about 20 c.c. of titrated oxalic acid

solution are added to the contents of the beaker, and 2 or 3 c.c. of sulphuric acid This is made up to about 60 c.c with water and heated to from 70° to 80° C while stirring. While yet warm, the titrated potassium permanganate solution is gradually measured in the solution, until a last drop produces a permanent coloration If it is then found that 8.7 c c. of permanganate solution has thus been added, then 20−8.7 =11 3 c.c of oxalic acid solution has been neutralized by the MnO_2 in the beaker, and, since each c c is equivalent to 1 milligramme of manganese, the sample treated contains 11.3 milligrammes of manganese or 1.13 per cent. The presence of the asbestos does not obscure the final indication.

2. A second method consists also in preparing two titrated solutions as follows:

a Ferrous sulphate, $FeSO_4+7H_2O$, 10 114 grms. in 1 litre of solution. Each c c. of this solution is equivalent to 1 milligramme of Mn in MnO_2, as shown by the equation:

$$2FeSO_4+MnO_2+2H_2SO_4=Fe_2(SO_4)_3+MnSO_4+2H_2O.$$

b. Potassium permanganate, $KMnO_4$, 1.15 grms. in 1 litre of solution. The $KMnO_4$ in 1 c c of this solution will oxidize the ferrous salt to ferric salt in 1 c.c of the above ferrous sulphate solution, in accordance with the equation.

$$2KMnO_4+10FeSO_4+8H_2SO_4 \\ =K_2SO_4+2MnSO_4+5Fe_2(SO_4)_3+8H_2O.$$

The sample to be analyzed is treated as in the foregoing method The contents of manganese is also obtained by the difference of the portion of ferrous salt neutralized by $KMnO_4$, subtracted from the whole amount of ferrous salt solution added to the steel or iron solutions, this difference giving the amount neutralized by MnO_2, which is a compound of all the manganese originally contained in the sample.

Passive State of Iron.—Plunge iron in concentrated fuming nitric acid. This renders the surface of the iron inattackable by acids, and the iron becomes therefore indissoluble in the acids, unless the skin so formed is mechanically removed.

45. METALLIC ALLOYS.

Uses, Resistance, etc.

Minimum Percentage of Metals in Paying Ores.

Name of Metal	Per Cent Metal in Ore	Name of Metal	Per Cent Metal in Ore
Iron	25 to 40	Tin	1 to 1 5
Lead	20 to 25	Mercury	1 to 2 5
Zinc	20 to 25	Silver	0 0005 to 0 001
Antimony	20 to 25	Platinum	0 0001 to 0 0002
Copper	2 to 2 5	Gold	0 000001 to 0 00001

Alloys of Copper and Tin.

Designation of Alloy	Copper, Per Cent	Tin, Per Cent	Designation of Alloy	Copper, Per Cent	Tin, Per Cent
Coin, bronze	98	2	Bearings	88	12
	96	4	"	90	10
	93 5	6.5	"	96	4
Gun, ordnance	90	10	Piston packing	92	7 & 1Zn
Statuary	89	11	" "	90	9 & 1Zn
Bell, Large	82	18			
Bell	77	23			
Bell, Small	70	30			
Speculum metal	67	33			
	70	30			
David Ross' Cu_4Sn	68.25	31 75			

Ordnance Bronze.

(According to U. S. Ordnance Manual.)

The copper used not to contain any appreciable quantity of sulphur, to contain not more than 0 001 part of arsenic and antimony united, not more than 0 003 lead, iron, or oxygen. Should be rejected if it contains more than 0 005 parts of foreign substances altogether.

The tin should be rejected if it contains 0 001 arsenic and antimony or more, or if it contains 0 003 part of lead, iron, and more than 0.004 foreign substances altogether When tin is run into elongated drops, these should be bright and smooth without rough spots.

The bronze should be rejected if it contains 0.001 or more parts of arsenic and antimony united, more than 0 003 of lead, iron, or zinc, and if it contains 0 005 or more foreign substances in all.

When broken, gun metal should have a fine close-grained fracture and should be ductile

Bronze used for rifled howitzers of the navy is made of Lake Superior copper, 9 parts, tin 1 part, when cast in sand molds, and of 10 parts copper, 1 part tin, when cast in chill molds

The copper is melted in a reverberatory furnace and when perfectly fused the tin is stirred in for half an hour, when the bronze is cast in the chill, the latter is previously heated to drive all moisture out

Phosphor-bronze.

Employment	Copper	Phosphor-Tin	Brass	
			Copper	Zinc
Journal for heavy main shafts	85	15		
Boxes for connecting and coupling-rods [1]	90	10		
Substitute for ordinary bronze [2]	16	4	65	35
Employment	**Copper**	**Tin**	**Phosphor-Copper**	**Zinc**
Journal for heavy main shafts.	88	12	1.75	
Boxes for connecting and coupling rods.	90	10	1 5	
Piston rings, valves, and valve-seats, pinions.	85 5	8	3 5	3
	77.85	11	3 5	7.65
Cog-wheels, propellor-screws, hydraulic press pumps	74 5	11	3.5	11
Piston-rods, bolts for cylinders.	72.5 to 7.53	8	2.5 to 1.5	17 to 19

[1] Can be forged cold. [2] Was used for wire ropes in mines.

Phosphor-copper.—(1) 4 parts superphosphate of lime, 2 parts granulated copper, 1 part finely pulverized coal Heat in a crucible at not too high a temperature. The phosphor-copper collecting at the bottom contains 14 per cent phosphorus.

(2) To a copper-sulphid solution add phosphorus; boil. As long as copper phosphid is precipitated add phosphorus. Collect the precipitate carefully dry, melt and cast in ingots. The substance should be quite black.

Phosphor-tin.—(1) Collect, and wash the spongy tin from a solution of tin chlorid, $SnCl_2$, in which a bar of zinc has been placed. Take 100 parts tin and 3 parts phosphorus, cover the sticks of phosphorus at the bottom of a crucible with this

yet moist tin sponge, pressing it tightly Heat gently until phosphor flames are no longer observable on the crucible. The tin-white, coarsely crystalline phosphor-tin will collect at the bottom. Melts at 370° C = 700° F

(2) 3 parts phosphoric acid (anhydrous), 6 parts tin, 1 part carbon. Melt in a crucible

By replacing in the composition, of ordinary bronze 0.1 part of the tin by phosphor-tin the bronze is greatly improved in soundness and toughness

In using phosphor-tin in the manufacture of phosphor-bronze avoid the employment of zinc in the bronze.

Process of Ruoltz and de Fontenay.—(3) Mix the sirupy acid phosphate of copper with 0 2 of its weight of charcoal and melt in a plumbago crucible, cast ingots of about 1 kilogramme. 2 2 lbs. The resulting compound is quite brittle and can be broken with light blows in the hand

This phosphor-copper contains about 15 per cent of phosphorus. It is preferable for the manufacture of bronze, as it can be employed for alloys containing no tin, as yellow brass German silver, etc , and for pure copper.

Preparation of Phosphor-bronze.—Melt the copper first, covering with charcoal, add the required quantity of tin, zinc etc., and when completely melted, add, according to circumstances, 1.5 to 3.5 per cent of phosphor-copper, while continually and carefully stirring with a bar of graphite or of retort carbon. Skim carefully the coal and scoriae on top; pour before a skin forms on the surface

Ordinary bronze and phosphor-bronze remelted should be treated the same way. If the surface of the remelted metal should not be bright, a small addition of phosphor-copper should be made.

Remarks.—The function of the phosphorus in melting bronzes consists in a deoxidizing action on the metals forming the alloy The oxygen of the oxids of the metals, intermixed in the mass of the molten alloy, is consumed by the phosphorus present, thereby reducing the oxids to the metallic state. The anhydrous phosphoric acid so formed, being eliminated from the molten metal mass, changes the latter from a combination of metals, intermixed with impurities into an alloy of pure metals.

The so-purified alloy, therefore, should not contain any phosphorus, or should contain it only as a very small excess of the phosphid introduced in the melt.

Bronzes, or Copper-tin Alloys.

Employment	Composition		Tenacity, Pounds per Sq. In.	Fracture	Remarks
	Copper	Tin			
Copper.	100	00	28,000 24,200	Fibrous	Mean of 9 samples
English ordnance. . .	91 74	8 26			
Prussian ordnance. .	90 91	9 09	32,000		
French ordnance. . .	90 73	9 27			
" " . . .	90 1	9 1			
U. S. ordnance. . .	90 00	10 00	27,000	Earthy	
" " . . .	89 29	10 71	26,000		
U. S. ord. gun-heads.	89 29	10 71	25,800		Mean of 12 samples
Jewelers' punches.	83.30	16 70			
Chinese gong	80 43	19 57			
Bells, 300 years old .	81 00	19 00			
Bells, best metal . .	78 00	20 00			
Bells, 600 years old .	76 20	23 80			
Mirror of telescope. .	68.82	31.18			
Mirror metal. ..	68 21	31 79			
White bell.	60 00	40 00			
" "	40.00	60.00			
Phosphor-bronze. . .			140,000		Hard
"			56,000		Annealed
Babbit metal.	10	90			

Brass, or Copper-zinc Alloys.

Name and Uses	Composition		Color	Fracture	Tenacity, Pounds per Sq. In.
	Copper	Zinc			
Tambac.	91 00	9 00	Yellow-red		26,000
French oreide ...	90 00	10 00	Red-yellow		26,500
Ornamental casting	86 00	14 00	Yellow-red		29,000
Tombac of Oker.	85 00	15 00	Red-yellow	Earthy	30,000
Bronze powder ..	83 99	17 00	Red-yellow		
Vienna gold leaf.	77 9	22 00	Yellow	Earthy	35,000
Ship sheathing ...	74 62	25 38	Yellow		30,000
Sheet brass	74 48	25 52	Yellow	Finely crystalline	29,000
Chrysorin ...	72 00	28 00	Yellow		
Bristol metal.	67 2	32 8	Yellow	Earthy	
Common brass	66 66	33 33	Yellow		28,000
Brass wire	65 4	34 6	Yellow		35,000
Hard solder . .	61 25	38 75	Red-yellow	Earthy	
Muentz metal	60 00	40 00	Red-yellow	Earthy	41,000
Sheathing for ships.	59 5	40 5	Red-yellow	Earthy	42,000
Brass, very ductile	54 9	45 1	Red-yellow		45,000
German brass	49 47	50 53	Yellow	Crystalline	20,000
Solder for brass	33 34	66 66	Yellow		
White button ..	19.65	80 35	Ash gray	Crystalline	4,000

Copper, Tin, Zinc, and Other Alloys.

Name	Composition Copper, Cu	Tin, Sn	Zinc, Zn	Name	Composition Copper, Cu	Tin, Sn	Zinc, Zn
Statuary bronze	65	3	32	Gold, imitation.	81 5	0 5	8
	58	17	25	Bronze for medals.	80	3	17
	85	5	11	Metal for general use	90	5	5
Telescope mirrors.	50	28	22	Journal bearings...	•75	12	3
Buttons, soft . ..	88	6	6				
Buttons, hard. . ..	84	8	8				
Chryscolle . .	88 5	5 75	5 75				

Manganese bronze. .	88 Cu	10 Sn	2 Mn
Babbit hardener. . ..	4 Cu	12 Sn	8 Sb
Babbit box-lining. ...	1 hardener	2 tin	
Plumbers' solder. . .	1 tin	2 lead	
Stereotype.	17 tin	67 lead	16 antimony
Sterpo-metal .	55 04 Cu	42.36 Zn	0.83 Sn 1.77 Fe
Aluminium bronze. .	90 Cu	10 Al	
U. S. Nickel coin metal	75 Cu	25 Ni	

Influence of Small Quantities of Certain Metals on Alloys.—0.007 per cent of antimony unfits lead for the manufacture of white lead

0.5 per cent of iron in copper reduces its electric conductibility to 40 per cent.

0.1 per cent magnesium or 0.3 per cent phosphorus added to nickel makes it, from brittle, malleable.

0.08 per cent of manganese or magnesium added to steel increases its malleability

A small addition of tin, from 1 to 5 per cent., to a brass alloy of nearly equal parts of copper and zinc, the copper being about 55 to 58 per cent of the alloy, may increase the tenacity of the alloy over 100 per cent ; from a minimum of about 40,000 and less to a maximum of over 85,000 pounds per square inch of section

As a matter of great importance to brass founders, machinists, electricians, engineers, and contractors special attention is called to the tables of tenacity of simple metals and of the alloys compounded therefrom, contained on pages 208 and 209, and to the subject matter relating to the same and other properties of alloys contained on page 210 For detailed information on this subject consult R H Thurston, ' Materials of Engineering" John Wiley and Sons, Scientific Publishers New York.

CLASSIFIED TABLES OF ALLOYS.

Copper, Zinc.

Red Brass	Copper	Zinc
1. Pinchbeck	93.6	6.4
2. Austrian journal boxes	92.5	7.5
3. Oreide, French	90	10
4. " "	85.5	14.5
5. Ornaments, English alloy	86.38	13.62
6. " " , Tournay	82.54	17.46
7. Imitation Halberland	87	13
8. Buttons, Tessier	97	2
9. Tombac, common	71.5	28.5
10. Tombac, Arcet, gilded	82.3	17.7
11. Tombac, Hegormuhle, Paris	85.3	14.7
12. Tombac, red, Paris	92	8
13. Tombac, red, Vienna	97.8	2.2
14. Tombac, leaf, Ludenscheid	99.15	0.85
15. Tombac, leaf, Ludenscheid	84.21	15.79
16. Bronze powder	84	16
17. Leaf bronze	84.6	15.4
18. Leaf bronze, gold, Vienna	77.9	22.1

Yellow Brass	Copper	Zinc
19. Malleable brass	70.1	29.9
20. Malleable brass, Lüdenscheid	72.73	27.27
21. Chrysorin	72	28
22. Common brass	66.6	33.4
23. Muntz metal, Bobierre	74.62	25.38
24. Bobierre, low grade	59.5	40.5
25. Brass wire, good	65.4	34.6
26. Brass wire, ductile, Storer	54.0	46.0
27 Malleable brass, Mecht	65.24	34.76
28. Malleable and ductile	66.0	34.0
29. Malleable brass, Vesslers	58.3	41.7
30. Chrysorin, Rauchenpergers	66.7	33.3
31. Bristol brass	75 7	24.3
32. Bristol brass	60 8	39.2
33. Mosaic gold	65.3	34.7
34. Brass solder	61.25	38.75
35. Brass solder, strong	33.34	66.64
36. Bath sheathing	55	45

White Metal	Copper	Zinc
37. Platine	43	57
38. Button, Lüdenscheid	20	80
39 Mallet, preservative of iron	25.4	74.60

Copper, Zinc, Tin.

Tombac Alloys, Bronze-like	Copper	Zinc	Tin
40. French	80	17	3
41. Golden bronze	89.97	9.96	0.07
42. Ornaments	82.0	17.5	0.5
43. British Navy	62	37	1

ALLOYS FOR TECHNICAL USE.

Copper, Zinc, Tin.

Designation	Copper	Zinc	Tin
44. British Navy screw-propellers..........	87.65	4.03	8.32
45. Eccentric straps.	83	2	15
46. Connecting-rod boxes...............	84	2	14
47. " "	82	2	16
48. " "	85.25	2	12 75
49 Locomotive axle....................	80	2	18
50. " "	82.25	2	12 75
51. " "	89	3	8
52. Car and locomotive	89	8 5	2 5
53. Valves, cocks, etc..	88	2	10
54. Pumps.	86	0.8	12 4
55 Piston ring (Seraing).................	89	9	2
56. Axle-bearing (French).	82	8	10
57 " , hard (G B).	87.05	5 07	7.88
58. Whistles, dull..	81	2	17
59 Stuffing-box (Belgian).................	90.2	6.3	3.5
60. Axle-bearings, wagon................	78	2	20
61. Brass, best quality	65.5	33.0	0.5
62. " " "	74.5	25.0	0.5
63. " " "	79.5	20	0 5
64. " , Tobin s	58.22	39.48	2.30
65. Bearings, cheap....	56	16	28
66. " "	58	14	28
67. " "	5 5	80	19.5
68. British Woolwich for sheathing nails.....	87	4.3	8.7
69. Medals...	97	2	1
70. Coins (old French)...........	95	1	4
71. Pistons and rods.	74 1	22.2	3.7
72. Casting upon iron..	78.7	15	6.3
73. Gearing.	88.8	2 7	8.5
74 Weights (Chemical Bl.)............. .	90	2	8
75. Mathematical instruments.............	82.1	5.1	12.8
White Alloys.			
76. Bristol..............................	57.9	36.8	5.3
77. "	61.12	36.11	2.77
78. White solder, soft....................	57.44	27.98	14.58
79. Bell, Herbohn........................	60	5	35
80. Jackson's	63.88	36.85	5.55
81. "	63.01	35.61	1.39
82. Mirror, good lustre....................	50	21.40	28.60
83. Bell, Herbohn.........................	71.43	2.17	26.40
84. Pump-cocks..........................	7	72	21
85. Rolls for print-work..	5	78.3	15.8
86. Bearings.	4.2	66.5	29.3
87. Anti-friction, Fenton..................	5.5	80	14.5
88. " , Manchester.............	5.69	76.14	17.47
89. " , English.................	7.40	67.70	14.9

Attention is called to the fact that the alloys in the tables above are technically applied, where the requirements are great resisting power against frictional abrasion, as in bearings, or against impacts, and the corroding actions of water and other liquids, as in pumps and valves, or finally, against powerful mechanical strains, as in gearings, propeller blades, and piston-rods.

Copper, Zinc, Tin, Lead.

Designation	Copper	Zinc	Tin	Lead
90. Statuary, Potsdam. ...	88.68	1.28	9 20	0.77
91. " , " , Bachus .	89 34	1 63	7.5	1.21
92. " , Louis XIV	91.4	5 53	1.7	1.37
93. " , Henry IV, Paris. . . .	89.62	4.2	5.7	0.48
94. " , Napoleon I, Paris. . .	75	20	3	2
95. " , Clm. Vendome, Paris	89 2	0.5	10.2	0.1
96. Objects to be gilded. . . .	63 7	33.55	2.5	0.25
97. " " "	72 43	22 75	1.87	2.97
98. Wire, English.	70 29	29.36	9.28	0.17
99. " , Augsburg.	71 89	27 63	—	0.85
100. Leaf, Aix-la-Chapelle.	64 8	32 8	2	0.4
101. White, for buttons.	48 5	33 32	6.06	12.12
102. " "	58 71	33 03	5.50	2.75
103. Berthier alloy.	71 9	24 9	1.2	2
104. Sundry alloys.	61 6	35 3	0.6	2.5
105. " "	63 7	33 5	2.5	0.3
106. Clockwork.	60 66	36 88	1.35	0.74
107. "	66 06	31 46	1 43	0.88
108. Oreide bronze.	68 21	31 52	0 48	0.24
109. Oker brass.	64 24	37 27	0.59	0.12
110. Sheathing nails.	63 6	25	2.6	8.8
111. Solder, yellow, hard.	53 3	43 1	1.3	0.3
112 " , " , soft. . . .	44	49 9	3.3	1.2
113. Machinery, brass.	74 4	8.9	9.5	7.1
114 Bearings, engine.	79	5	8	8
115. Pistons, engine. . .	84	8 4	2.9	4.7
116 Parts at high temperature. .	90 7	5 3	2.7	1.3
117 Gold-colored	74	10	1	15
118 " harder.	70	10	10	10
119 Parts, heavy friction.	83	1.5	15	0.5
120. Sheathing nails (Percy).	63 6	24 6	2 6	8.7
121. Chinese white metal.	72.5	14.3	4.7	18.5
122. Soft metal.	3	40	15	42
123. Common spelter.	4.4	1 5	82.3	11.8
124. Pewter	5 7	1.6	81 2	11.5
125. Heine's alloy	11.4	84.3	1.4	2.9
126. Erhardt's alloy.	4	89	4	3

Copper, Tin, Antimony.

Designation	Copper	Tin	Antimony
127 Bronze.	87	12	1
128. Steam-whistles.	80	18	2
129 Westphalian alloy	7	82	11
130. Magdeburg alloy.	11	74	15
131. Berlin alloy.	5	85	10
132 Anti-friction (Kamarsch).	3 7	88.89	7.41
133. " "	6.25	81.25	12.50
134. " "	9.76	70.73	19.51
135. " French R R.	5	71	24
136. " (Kamarsch).	21.44	71.41	7.14
137. " Fenton.	5.5	80	14.5
138 Anti-friction, English.	7.80	76.70	15.50
139. " "	2	72	26
140. " Bavarian	2	90	8
141. " Ludenscheidt	4	72	24
142 Britannia, Birmingham.	1.50	90.6	7.2
143. " , Asberry.	2.8	77.8	19.4
144. " , cast.	0.09	90.71	9.2

BRONZES.

Copper, Tin.

Designation	Copper	Tin
145. Bell, white, silvery	78	22
146. " , Reichenhall	80	20
147. "	60	40
148. "	75 2	24.8
149. " , Herbohn	75	25
150. " "	73	27
151. Gun-metal, British	91 74	8.26
152. " , Prussian	90 90	9.10
153. " , French Medals	90 1	9.9
154. " , common	90 7	8.3
155. " , "	89.3	10.7
156. Mirror, Cu;Sn	68 21	31.70
157. " , Mudge	68 82	31.18
158. " , Laderig	69	28.7
159. Medals	93 5	6.5
160. "	92	8
161. Machinery, malleable	98 04	1.96
162. Eisler's yellow bronze	94.1	5.9
163. Gearing	91.3	8.7
164. Bearing, Koechlin	90	10
165. " , Seraing	86	14
166. " , carriage wheels	84	16
167. Bronze for stamping	83 3	16.7

GERMAN-SILVER ALLOYS.

Copper, Zinc, Nickel.

German Silver	Copper	Zinc	Nickel
Common	55	25	20
Wagner's	50 66	19 31	13.18
Chinese	26.3	36.8	36.8
" , poor	43 8	40 6	15 6
" , tutenag, amber, hard	45 7	39 9	17.4
Sheffield, common, yellow	59.3	25.9	14.8
" silver-white	55.2	24.1	20 7
" electrum, bluish	51 6	22.6	25 8
" hard	45.7	20	31.3
Berlin, richest	52	26	22
" medium	59	30	11
" lowest	63	31	6
French Arcet	50	31.3	18 7
" "	50	30	20
" Chaval	58 3	25	16.7
Austrian, Gersdorff	50	25	25
" "	55 6	22.2	22.2
" malleable	60	20	20
Fricke's bluish yellow, hard	55 5	39	5 5
" pale yellow, ductile	62 5	31 2	6 3
" silvery, hard	50	18 8	31.2
" " , harder	59	30	10

Bronzes of normal composition are mainly employed in machinery, in military and naval appliances, where toughness and great resisting power against sudden strains are required.

Copper-Nickel; Copper, Tin, Nickel.

Designation	Copper	Tin	Nickel
United States old coin.	81 85	—	18.15
" " first legal standard.	85	—	15
" " and Belgian, recent	75	—	25
Castings	52 5	28 8	17.7
Bearings	50	24 5	25 5
Berthier, bluish white	68.2	—	31.8
Melchoir iron, 3; zinc, 17.	55	2	23
Sheath for leaden bullets.	80	—	20

Copper, Zinc, Nickel, Iron, Cobalt.

Designation	Copper	Zinc	Nickel	Iron
Chinese Packfong.	40 4	25 4	31 6	2.6
Sheffield (German silver).	58 2	25.5	13 3	3
Parisian maillechort.	65 4	13 4	16 8	3.4
White, hard, and brittle.	48 8	24 4	24.4	2 4
" " " "	53	23	22	2
				Cobalt
English German silver.	60	17.8	18 8	3.4
" " " elastic	57	25	15	3
			Tin	Iron
Sterro-metal	55–60	36–41	1–2	1–2

Copper, Zinc, Tin, Bismuth.

Name of Alloy	Copper	Zinc	Tin	Bismuth
White, sonorous, hard.	2 1	—	97.3	0.6
" Algerian.	2.4	—	97	0 6
Tinning iron.	5 1	10.3	76.9	7.7

Copper, Zinc, Tin, Antimony, Bismuth.

Name of Alloy	Copper	Tin	Zinc	Antimony	Bismuth
Pewter leaf.	1 8	89 3	—	7 6	1.8
" "	6 8	84 7	—	1 7	6 8
" "	1 6	83.3	6 6	6 6	1.6
Britannia	3 6	85	1 4	5	5
" fine	0.81	85.64	6.06	9.66	0.83

Various Alloys of Lead and Tin with Other Metals.

Name of Alloy	Tin	Lead	Antimony	Bismuth	Arsenic
Queen's alloy.	9	1	1	1	—
Perrotine's for rolls	48	32 5	10 5	9	—
Shot-metal.	—	100	—	—	0.4–3.0

Type Metal.

Note.—In the column of sundries Cu = copper, Zn = zinc, Al = aluminium.

Designation	Lead	Antimony	Tin	Sundry Metals
Type metal, medium.	16	1	—	—
" " soft.	34	1	—	—
" " hard.	4	1	—	—
" " "	—	—	59	Zn 33
" " "	70	18	10	Cu 2
" " sharp, resisting.	16	4	—	Al 1 to 3

Solders for Joining Various Metals.

Designation of Solder.	Lead	Tin	Zinc	Copper	Brass	Silver	Gold	Bismuth	Flux
Plumbers, coarse.	3	1	–	—	—	—	—	—	Rosin
" fine.	2	1	—	—	—	—	—	—	"
Tinners, fine.	1	2	—	—	—	—	—	—	Rosin or
" common.	1	1½	—	—	—	—	—	—	Zinc chlorid
For copper, brass, or iron.	—	25	43	30	—	—	—	—	Borax
" " " " "	—	—	1	2	—	—	—	—	"
" " " " " hard.	—	—	1	—	5	–	—	—	"
" " " " " yellow.	—	—	1	1	—	—	—	—	"
" silver and steel joints	—	—	—	1	1	19	—	—	"
" silver-plating.	–	—	—	–	1	2	—	–	"
Silver solder for brass or iron	—	–	—	—	1	1	—	—	"
" " fusible.	—	—	5	—	5	5	–	—	"
Solder for gold.	–	—	—	4	—	2	12	—	"
" fusible at 320° F	4	4	—	—	—	—	—	1	Rosin or
" " " 310° F	3	3	—	—	–	—		1	Zinc chlorid
" " " 202° F	3	5	—	—	—	—	—	3	" "
" "	4	3	—	—	—	—	—	2	" "

Amalgams.

Designation	Lead	Tin	Zinc	Mercury	Bismuth	Cadmium
Amalgam for plane mirrors.	—	70	—	30	—	—
" " curved mirrors.	—	4	—	1	—	—
" " " mirrors.	1	1	—	9	1	—
" " electric machines	—	1	1	2	—	—
" by Singer.	—	1	2	3 5-6	—	—
" anatomical	4	7	—	20	12	—
" cadmium.	—	—	—	74	—	26
" "	—	—	—	78.26	—	21 74

For special consideration it may be stated that the alloys of mercury with other metals, generally known under the name of amalgams, constitute a very extensive variety Besides the more common metals, the alkaline metals, potassium, sodium, etc., combine with mercury in almost unlimited proportions

Melting-points of Alloys of Lead, Tin, Bismuth.

(PARKS AND MARTIN.)

Parts			Melting-points		Parts			Melting-points		Parts			Melting-points	
Lead	Tin	Bismuth	Fahr	Centigrade	Lead	Tin	Bismuth	Fahr	Centigrade	Lead	Tin	Bismuth	Fahr.	Centigrade
			°	°				°	°				°	°
3	2	5	197	93	16	14	8	290	143 53	30	24	8	342	172.22
5	3	8	202	94 44	16	16	8	292	144 4	32	24	8	352	177.78
6	3	8	208	97 78	16	18	8	298	147 78	32	28	8	332	166.67
8	3	8	226	107 78	16	20	8	304	150 1	32	30	8	328	164 44
8	4	8	236	113 33	16	22	8	312	155 55	32	32	8	320	160
8	6	8	243	117 22	[2]16	24	8	316	157 78	32	34	8	318	158 89
[1]8	8	8	254	123 33	18	24	8	312	155 55	32	36	8	320	160
10	8	8	266	139 0	20	24	8	310	154 44	32	38	8	322	161 11
12	8	8	270	132 22	22	24	8	308	153 33	32	40	8	324	162 22
16	8	8	300	148 89	24	24	8	310	154 44				[3]Ca	d.
16	10	8	304	151 1	26	24	8	320	160	2	1	4	1	61
16	12	8	294	145 55	28	24	8	330	165 55	8	4	15	3	62

[1] Perrotine alloy. [2] Printing-rolls. [3] Cad. = Cadmium.

Melting-points of Tin, Lead.

Parts		Melting-points		Parts		Melting-points		Parts		Melting-points		Parts		Melting-points	
Tin	Lead	Fahr.	Centigrade	Tin	Lead	Fahr	Centigrade	Tin	Lead	Fahr	Centigrade	Tin	Lead	Fahr.	Centigrade
		°	°			°	°			°	°			°	°
[1]4	4	332	166.7	4	6	412	211 67	4	28	527	275	4	50	551	288 3
6	4	336	169	4	8	442	228 3	4	30	530	276.7	4	52	552	288 9
[2]8	4	340	171	4	10	470	243 3	4	32	532	277 8	4	54	554	290
10	4	348	175 5	4	12	482	250	4	34	535	279 4	4	56	555	290 5
12	4	356	180	4	14	490	254 4	4	36	538	281 1	4	58	556	291 1
14	4	362	183 3	4	16	498	258 9	4	38	540	282 2	4	60	557	291.7
[3]16	4	367	186 1	4	18	505	262 8	4	40	542	283 3	4	62	557	291.7
18	4	372	188 9	4	20	512	266 7	4	42	544	284 4	4	64	557	291 7
20	4	378	192.2	4	22	517	269 4	4	44	546	285 5	4	66	557	291.7
22	4	380	193 3	4	24	519	270 5	4	46	548	286 7	4	68	557	291 7
24	4	382	195	4	26	523	272 8	4	48	550	287 8	4	70	558	292.2

[1] Common solder [2] Fine solder [3] Pewter

Solutions of metals in metals.—Mercury, at ordinary temperatures, will dissolve lead, tin, zinc, and other metals in almost unlimited quantities, forming amalgams. Among the other metals, as of special importance, may be mentioned silver and gold. The most important metallurgical process of their extraction from the ores is based on this very property of

mercury to dissolve, with facility and instantaneously on coming in contact therewith these precious metals Some metals seem to be insoluble in mercury, like iron, and some, like copper, only slightly soluble. The fact that copper plates are subject to amalgamation by mercury is proof that a small amount of copper is dissolved at their surfaces; but since the amalgamation does not penetrate deeper in the mass of the copper, the indications are that the amalgam of copper so formed while holding unalloyed mercury by the force of adhesion constitutes an impenetrable skin for the overlaid and adjacent coat of mercury, destined to abstract the silver or gold from the kernels of crushed gold-bearing quartz passing in a stream of water over it.

A number of metals when in a molten or liquid state have the property of dissolving other metals in various proportion. Lead will dissolve gold, silver, antimony, tin, zinc, and other metals, in relatively great quantities, while copper, iron, and similar metals seem to be only sparingly soluble in it The innumerable alloys, which can be formed with copper, zinc, and tin, seem to indicate that these metals are soluble in each other in considerable proportions.

While iron is hardly soluble in any metal, the fact that the surface of the sheet iron can be supplied with an adhesive coating of tin or zinc, shows that some of the iron must combine with these metals and form coatings of alloys probably of definite atomic proportions, to which a small quantity of the pure molten metal will adhere forming the real coat of tinned or galvanized iron.

There is a probability that metals dissolved in this manner in each other form combinations of definite atomic proportion.

Analysis of Metals.

Impurities	Lake Superior Copper	Banca Tin	Ingot Queensland Tin
Specific gravity	8 487	7 293	
Pure	99 42	99.978	99.794
Iron	0 013	0 035	0 035
Silver	0.014	—	—
Suboxid of copper	0 537	—	—
Carbon	0 041	—	—
Lead	—	—	0 165
Manganese	—	—	0 006

45a. TENACITY OF VARIOUS METALS AND ALLOYS.

MAINLY FROM U. S. BOARD ON TESTS.

Tenacity	Pounds per Square Inch			Maximum Extension, Per Cent	Elastic Limit, Per Cent	Kilogrammes per Sq. Centimetre		
	Maximum	Minimum	Average			Maximum	Minimum	Average
Copper, cast	29800	15000	24000	7.5	49.1	2086	1050	1680
Copper, forged	40000	25000	33000	...	...	2800	1750	2310
" sheet, and bolts	...	...	35000			...	...	2450
" wire, hard		...	60000		...	...	...	4200
" with 0.015 phos.	...	...	38000	...	...	...	...	2960
" " 0.02 "	...	...	45000	...	...	...	...	3150
" " 0.04 "			50000	...	...	...	...	3500
Tin, cast	4000	2000	3000	42	47	280	140	210
Zinc, cast	6000	5000	5500	0.48		420	350	385
Lead	2400	1600	2000			168	112	140
Aluminium	28000	15000	21500	...	50	1960	1050	1500

Copper, Zinc, Tin Alloys of Greatest Tenacity.

No.	Composition			Tenacity, Lbs per Sq. Inch Average.	Tortion Breaking Angle, 2 Samples, Deg.	No.	Composition			Tenacity, Lbs. per Sq. Inch Average 2 Samples	Tortion Breaking Angle, 2 Samples, Deg.
	Copper	Zinc	Tin				Copper	Zinc	Tin		
1	55	43	2	74,800	40-43	13	55	45	0	61,000	52-65
2	54	44	2	56,600	5-40	14	52	46	2	51,100	5-7
3	54	43	3	70,800	14-10	15	52	43	5	62,600	4-5
4	55	42	3	73,900	20-30	16	55	40	5	71,800	4-7
5	56	42	2	75,400	55-46	17	58	40	2	68,300	54-43
6	56	43	1	63,700	53-42	18	54	45	1	72,200	43-54
7	55	44	1	75,800	54-53	19	53	44	3	64,200	8-5
8	53	45	2	56,800	9-6	20	54	42	4	73,200	6-7
9	53	43	4	68,000	6-5	21	56	41	3	75,100	38-8
10	55	41	4	75,300	5-9	22	57	42	1	73,400	56-76
11	57	41	2	69,100	40-35	23	58	41	1	54,000	63-128
12	57	43	0	61,400	95-131	24	55	44.5	0.5	68,900	

Of 23 different alloys selected from a great number of copper, zinc, tin alloys, on account of their superior strength and toughness, and having compositions between

Copper	max.	58,	min.	52
Zinc	"	46,	"	40
Tin	"	5,	"	0

two samples of each having been tested.

Alloyed Metals of Maximum Tenacity.

Composition	Copper	Tin	Copper	Zinc	Copper	Zinc	Tin	Tobin's Alloy Copper	Tobin's Alloy Zinc	Tobin's Alloy Tin
Before melting original	82.50	17.50	57.5	42.5	57	41	1	58.22	39.48	2.30
After casting by analysis	82.70	17.34	58 49	41.10						
Tenacity, lbs per square inch	36,000		50,450		85,770					
" klgrms. per sq. cm.	2530.8		3533.5		6029.6					
Elongation, per cent of length	7		10							
Elastic limit, per cent	68		54.4							
Modulus of elasticity	15,152,700		11,850,000							

Metals of Maximum Ductility.

Composition	Copper	Tin	Copper	Zinc	Copper	Zinc	Tin	Copper	Zinc	Tin
Original	96.27	3.73	72 5	27.5	55	44.5	0.5	88 14	10	1.86
By analysis	96 06	3.76	73 2	26 47						
Tenacity, lbs per square inch	30,200		31,600		68,900			33,000		
" klgrms. per sq. cm.	2,250		2,221		4,844			2,320		
Elongation, per cent of length	14.3		38.5		9 to 10			19 5		
Elastic limit, per cent	50		23.7							
Modulus of elasticity	13,739,600		14,510,000		11,800,000					

Various Alloys of Maximum Tenacity.

Name of Alloy	Sterro-metal				Manganese-bronze			Aluminium bronze		Copper-iron Rolled		Phosphor-bronze	
Composition	Copper	Zinc	Tin	Iron	Copper	Tin	Manganese	Copper	Aluminium	Copper	Iron	Hard	Annealed
Per cent.	60	35	2	3	88	10	2	90	10	95 5	4 5		
Tenacity, lbs per square inch	84,900				67,000			100,000		4,000		159,000	64,000
" klgrms per sq. cm.	5,968				4,710			7,030				10,908	4,499
Elongation, per cent of length.					26			10					
Elastic limit, per cent.								60		88			

A ductile alloy of highest tenacity, 85,770 lbs. per sq. inch, 6030 klgm. per sq cm., was obtained from copper 57, zinc 42, tin 1; a tough metal of the highest average tenacity, 75,826 lbs. per sq. inch, 5330 klgm. per sq. cm, of two samples of the same composition, was obtained from copper 55, zinc 44, tin 1; the lowest tenacity, 45,038 lbs. per sq. inch, 3166 klgm. per sq. cm from copper 58, zinc 41, tin 1; was very ductile. A brittle alloy of lowest average tenacity, 51,139 lbs. per sq. inch, 3595 klgm per sq. cm, of two samples of the same composition, was obtained from copper 52, zinc 46, tin 2. The alloys of highest ductility were

Copper 57, Zinc 43, Tin 0;
Copper 58, " 41, " 1

Alloys highest in tenacity and ductility combined considered as the best metals:

Copper 55, Zinc 44, Tin 1;
Copper 57, " 42, " 1.

In order to prevent oxidation in melting these alloys, phosphorus was added in the shape of phosphor-tin, which is commercially produced containing in 100 parts, 95 tin and 5 phosphorus.

Liquation.

Liquation or the separation of melted alloys into two or more separate compositions while cooling, should be avoided.

Bronzes or copper tin alloys, when cooled quickly, as is the case when cast in chill molds, are less subject to liquation than when cooled slowly or when cast in sand molds.

It is generally considered that quick cooling prevents to a great extent liquation in any alloy.

45b. SPECIAL ALLOYS AND COMPOSITIONS.

Platinum-Iridium.—By composition, 98 5 platinum; 12.5 iridium; by analysis, 90 platinum; 10 iridium.

Spence's "Metal."—Discovered by Spence in 1879. It is a solution of metallic sulphids in molten sulphur, and is, therefore, not a metal. Specific gravity 3.37 to 3 7. Melting-point 320° F.=160° C; expands on cooling.

Uses—In laboratory for joints between caoutchouc and glass. Solder for gas-pipes. For joints in place of lead. For

45c. BRONZING LIQUIDS FOR METAL ALLOYS.

Reference Number	For Brass by Immersion and Brushing	Color	Dissolve in 1 Pint of Water		Reference Number	15 to 18 for Copper 19 to 26 for Zinc	Color	Dissolve in 1 Pint of Water	
			Oz.	Dr.				Oz.	Dr.
1	Nitrate of iron	Brown to Black		5	15	Nitrate of iron	Brown		5
	Perchlorid of iron			5		Potassic sulphocyanid	Black		2
2	Nitrate of iron	Red to Brown		16	16	Copper sulphate		1	
	Hyposulphite of soda			16		Sodic hyposulphite	Dark brownish-drab	1	
3	Nitric acid	Red-brown		1		Hydrochloric acid			2
	Hyposulphite of soda			16	17	Pearl-ash	Bright-red	1	
4	Oxalic acid	Brown-red	1			Sulphid of antimony			2
	Nitrate of copper		1		18	Pearl-ash	Red to black	1	
5	Nitric acid	Brown-red		3		Sulphur			1
	Ferricyanid of potassium			1	19	Protochlorid of tin			1
6	Nitric acid	Dark-brown		4		Potassic sulphocyanid	Dark gray		1
	Ferrocyanid of potassium		1		20	Muriate of lead			
7	Pearl-ash	Yellow to red		6	20	Copper sulphate			0.5
	Persulphid of arsenic			½		Iron muriate	Dark gray		0.5
8	Sulphur and potash	Orange		1	22	Iron muriate	Green-gray		0.5
9	Permuriate of iron	Olive-green		1	23	Pearl-ash		4	
10	Perchlorid of i on			5		Copper sulphate	Copper color		4
	Potassic sulphocyanid	Slate		2	24	Sodic hyposulphite			8
11	Hyposulphite of soda	Blue		20		Copper sulphate	Copper color		8
12	Muriate of arsenic	Gray	1		25	Garancine, boiling infusion	Red		
13	Permuriate of iron			2					
	Muriate of arsenic	Black	10		26	Logwood, boiling infusion	Purple		
14	Chlorid of platinum								

No. 4 boiled and cooled; No. 5 one hour for results; No. 12 heat to 82° C. = 180° F.

clear castings of perfect impressions Insoluble in water resists the action of most acids and alkalies

Silicon-Bronze.—(1) Reduce silica in the crucible by means of sodium. Add melted copper or bronze

(2) Mix and heat in a plumbago crucible: Fluosilicate of potash, 450 grams; glass in powder, 600 grammes; chlorid of sodium (table salt), 250 grammes; carbonate of soda, 75 grammes; carbonate of lime, 60 grammes; chlorid of calcium (dry), 500 grammes When they begin to react on each other, put in the copper or bronze bath. Recommended as superior for telegraph lines.

LACQUERS FOR ALLOYS.

Shellac Varnish.

		Red			Yellow					
Shellac	Alcohol	Dragon's Blood	Annotto	Saunders	Turmeric	Gamboge	Saffron	Cape Aloes	Sanderac	Color Modification
oz.	pt.	dr.	dr.	dr.	dr.	dr	dr.	dr.	dr.	
4	1	—	—	—	—	—	—	—	—	
1	1	—	—	—	—	—	—	—	—	
1	1	—	—	—	—	1	—	3	—	Pale
1	1	—	—	—	1	1	2	—	—	
1	2	1	1	—	—	16	4	—	8	Plate-gold
2	2	1	8	—	32	—	—	—	8	"
2	1	—	—	—	—	2	—	4	—	Pale yellow
1	1	—	1	—	4	—	—	—	—	Full yellow
3	1	—	2	—	16	—	2	—	—	Gold
3	1	4	—	—	16	—	—	—	—	Deep gold
1	1	8	32	—	—	—	—	—	—	Red
1	1	—	—	—	20	—	—	2	5	Gold
3	1	4	—	—	1	—	—	—	—	Deep gold
1	1	8	32	—	—	—	—	—	—	Red
1	1	—	—	—	4	1	—	—	—	Green-bronze

Varnish.

		Red			Yellow				A, oz, Pyroacetic-ether B, oz., Spirits of Turpentine Varnish C, dr., Spirits of Turpentine D, mastic E, dr., Canada Balsam
Shellac	Alcohol	Dragon's Blood	Annotto	Saunders	Turmeric	Gamboge	Saffron	Sanderac	
oz.	pt	dr.	dr.	dr.	dr.	dr	dr.	dr.	
5	3	—	—	—	—	—	—	—	30 A, pale yellow
3	4	—	—	[illegible]	64	6	—	14	6 B, gold
3	1	40	—	12	10	—	—	—	30 C, deep gold
1	—	8	24	—	—	—	—	—	1 B, red
15	6	20	—	—	60	—	10	—	30 D, 30 E, tin

46. HYDRAULIC DATA.

Gravity.

The speed attained after one second of time by a body falling freely in vacuum is the acceleration due to gravity, and is in all books treating on the subject designated by the letter g This acceleration, g, expressed in feet or in metre per second, is largest at the poles of the earth and smallest at the equator, and it diminishes as the elevation of a place above sea-level increases.

The highest value for the United States at the sea-level of the northern limit thereof, about latitude 49° is g = 32.186 feet = 9 8103 metres; at latitude 25°, 10,000 ft above sea-level g = 32.089 ft

Formula for Calculating the Value of g for any Latitude and Altitude, by Pierce.

If l = latitude in degrees, etc , e = altitude in feet above sea-level, then

$$g = 32.0894(1 + 52375 \times 10^{-7} \times \sin^2 l)(1957 \times 10^{-10} \times e) \text{ feet.}$$

A mean value in the United States may be taken as g = 32.16 ft = 9 8024 metres

At the poles of the earth g = 32.258 ft = 9 83226 metres.

Atmospheric Pressure.—This pressure is usually measured by the length of a barometric column of mercury, the mean of which at 0° C = 32° F is considered to be 760 millimetre = 29 922 inches

This is equivalent to a pressure of 1 0333 kilogrammes per square centimetre, or 14 7 pounds per square inch surface.

The pressure per square inch of a column of water 1 foot high is = 0.434 pounds, and the height of a column of water of 1 pound pressure per square inch is = 2 304 feet

The height of a column of water or the head of water equivalent to atmospheric pressure or to a pressure of 14.7 pounds per sq. inch is = 33 868 feet = 10 323 metre.

The weight of 1 cubic foot of ordinary river and spring-water at mean temperature is approximately = 62.5 pounds.

Distilled water at maximum density, or 3 94° C = 39.1° F., weighs 62.426 pounds, and at its boiling-point under mean

atmospheric pressure, or at 100° C.=212° F, it weighs 59.84 pounds per cubic foot.

Ice per cubic foot weighs 57.2 to 57.5 pounds.

46a. FALLING BODIES.

Relations of Velocity, Space and Time.—If v = velocity of a falling body at the end of t = time in seconds during which the body falls, and h = height or space through which the fall takes place, then

$$v=gt \quad \text{or} \quad v=\sqrt{2gh} \quad \text{and} \quad h=\frac{gt^2}{2} \quad \text{or} \quad h=\frac{v^2}{2g},$$

velocity and height being expressed in the same units as g.

These laws are applicable to a falling body which meets with no resistance Such conditions, however, are only artificially obtainable, as in actual or usual experiments of this kind when a solid body falls through air it will encounter the frictional resistance of the same; when the falling body is a liquid it will gradually be subdivided into smaller particles by the action of this resistance, and the relations of velocity, space, and time will be greatly modified in such cases

When water from a great volume, such as may be contained in a tank, in a pond, or in a stream, issues through an orifice at a point lower than the level of the upper surface of the water, and under the supposition that no resistance is taking place, the jet so formed would have the velocity: $v=\sqrt{2gh}$, and the quantity q in cubic units of water flowing out of the area a in square units of the orifice would be:

$$q=av=a\sqrt{2gh}$$

h = to the height from the centre of the orifice to the top surface of the body of water, and all quantities being expressed in the same units as g.

It has been found, however, by experiment, that this quantity q is subject to great variations under different circumstances, and that the actual quantity q must be determined for each specific case by multiplying q with a coefficient c, so that the actual quantity will be $q_1=ca\sqrt{2gh}$

For an orifice in a thin wall as in sheet metal or through the sharp beveled edge of the thick wall of a tank, the bevel

being on the outside, an average value of the coefficient c will be about 0.62, so that

$$q_1 = 0.62a\sqrt{2gh}.$$

Discharge through tubes may vary considerably, changing with shape and relative length of the tubes.

Coefficients of Discharge Through Orifices in Thin Walls and Through Tubes.

Shape of Orifice	Diameter or Depth, Inches	Length, Feet	Head of Water, Feet	Value of Coefficient C	Tubes	Head of Water	Coefficient C
Circular. . .	0.25	—	0.4	0.65	3 diameters, long,		
" .	12	—	100	0.59	sharp inside corners,		
Square. .	0.25	0.25	0.6	0.66	small	low	0.83
"	0.25	0.25	100	0.599	large	high	0.80
" . . .	12	12	0.8	0.597	Inward projecting tube		0.72 to 0.82
" . . .	12	12	3	0.603			
" . . .	12	12	100	0.598	Rounded inner corners; outside conically enlarged		
Rectangular	1.5	$n\times0.125$	0.4	0.634			
"	1.5	$n\times0.125$	10	0.606			2.43
"	12	n	0.8	0.608			
"	12	n	20	0.601	Nozzles of best construction		0.97

The Miners' Inch.—What may be called the standard miners' inch is the quantity of water which will flow in a given time from a vertical standard orifice, 1 inch square, in a thin wall with a head of water above the centre of the orifice of 6.5 inches. This quantity is about 1.5 cubic feet per minute. This quantity, however, varies in different localities and ranges in California between 1.2 and 1.76 cubic feet of water per minute.

Table of Customary Miners' Inches.

Locality	Size of Orifice		Head of Water above Orifice		Discharge of Water in 1 minute, Cu. Ft.	Number of Miners' Inches
	Length, Inches	Height, Inches	From Centre, Inches	From Lower Edge, Inches		
Standard.	1	1	6.5	—	1.5	1
Smartsville, Cal.	250	4	—	11	—	1000
Columbia, Cal. .	12½	12	—	18	—	200
Montana.	n	1	4	—	$1.25n$	n

Vertical Jets from Smooth Conical Nozzles.

Pressure in Pounds per Square Inch	Height of Jet in Feet for Diameters in Inches of Orifice or Nozzle		
	1″	1¼″	1½″
	Feet	Feet	Feet
10	22	23	22
50	94	99	97
100	148	164	157

Discharge of Water Through Long Pipes.
Lampe's Formula.

If d = diameter of inside bore of pipe in feet;
l = length of pipe in feet;
h = effective net height, or head, of water in feet.
q = maximum quantity of discharge of water in cubic feet per second;
v = velocity of flow in feet per second, then:

$$v = 77.7 \times d^{0.694} \times \left(\frac{h}{l}\right)^{0.555}$$

$$d = 0.217 \times q^{0.371} \times \left(\frac{h}{l}\right)^{0.206}$$

$$q = 61 \times d^{2.694} \times \left(\frac{h}{l}\right)^{0.555}$$

46b. STREAMS AND WEIRS.

Flow of Water over Weirs.

If h = height in feet of level of still-water over lower sharp horizontal edge of weir;
b = breadth in feet between sharp vertical edges of weir;
q = quantity of water in cubic feet discharged per second;
c = coefficient of contraction or of discharge, then:

$$q = c \times \tfrac{2}{3}\sqrt{2g} \times b \times h^{\frac{3}{2}} = c \times \tfrac{2}{3} bh \times \sqrt{2gh}.$$

The number 0.644 may be taken as an average value for c, in which case the formula becomes:

$$q=0.43\sqrt{2g}\times b\times h^{\frac{3}{2}} \quad \text{or}$$

$$q=0.43b\sqrt{2gh^3}=0.43bh\sqrt{2gh}$$

Assuming $g=32$ feet, which is close enough for all practical purposes, then the formula becomes:

$$q=0.43bh\sqrt{64h}=3.44bh\sqrt{h}$$

Value of Coefficient C under Various Dimensions of Breadth, b, and Height, h, of Weir.

Height of Level of Still Water over Lower Edge of Weir h in Feet	Breadth of Weir b in Feet	Coefficient C
0.1	0.66 to 19	0.632 to 0.656
0.1	1	0.639
0.1	10	0.655
0.7	1	0.590
1.6	10	0.600

Flow of Water in Natural Streams and in Ditches and Canals

(Matter moved by flow of water at different speeds).

Speed in Feet per Second	Material Moved by Flow of Water	Speed in Feet per Second	Material Moved by Flow of Water
0.25	Fine Clay	3	Pebbles of about 1 inch
0.5	Loam and earth	4	Spalls and stones
1	Sand	6	Large stones
2	Gravel		

If v = measured velocity in feet per second of a stream of water;
a = area of cross-section in square feet;
q = quantity of water in cubic feet flowing per second, then:

$$q=av,$$

and if w = weight in pounds of the water flowing per second,

$$w=62.5\times q=62.5\times av.$$

Designating by Fp = foot-pounds of work per second and by

h = the head or height of fall in feet of the water above the level of the tail-race, then

$$Fp = wh = 62.5 \times qh = 62.5 \times ahv$$

and as a horse-power is equal to 33,000 pounds moved 1 foot high in 1 minute or $\frac{33000}{60} = 550$ pounds lifted one foot in 1 second of time, we find,

$$\text{Horse-power, H.P} = \frac{62.5 \times qh}{550} = 0.1136 \times q \times h$$

The best constructed hydraulic motor, however, does not transmit more than 0.90 of this power, and some may have an efficiency as low as 0.25 of the above theoretical power.

46c. Hydraulic Motors.

1. **Water-wheels,** which are distinguished as:

Overshot wheels in which the water-power is applied on top of the wheel

Breast Wheels, where the power is applied at or near the central part of the wheel, and

Undershot Wheels, where the power is applied at or near the under side of the wheel.

2 **Turbines** are generally horizontal wheels, but not necessarily so, they are distinguished in:

Outward-flow Turbines, in which the water is admitted through a central conduit or flume and performs its work while flowing towards the circumference of the wheel.

Inward-flow Turbines, where the stream of water is applied at the circumference and performs its work while flowing towards the centre, where it is discharged

Downward-flow Turbines, where the water is admitted at the rim of the horizontal wheel and performs its work while flowing downward.

3 **Reaction Wheels;** the water is admitted at the central part and performs its work by flowing outward through generally two hollow bent tubular buckets.

4 **Impulse Wheels:** water of considerable pressure is conducted to the wheel by a pipe, and performs its work by flowing out of a nozzle and impinging on the floats or buckets of the wheel.

5. **Piston Motors;** water enters a cylinder and moves a piston, which is connected to a crank and a fly-wheel.

47. WATER PURIFICATION.

Impurities in Water and its Purification.

Units of Impurities and Definitions.

Hardness.—This term designates the property of water, containing calcium, magnesium, and other salts in solution, to annul the effect of a certain amount of soap used with such water.

If soap in a general way is considered as a sodium stearate with the formula:

$$NaC_{18}H_{35}O_2$$

This compound, soluble in pure water, will be transformed into insoluble compounds by impurities in the following manner, when the impurities consist in carbonate or sulphate of lime:

$$CaCO_3 + 2NaC_{18}H_{35}O_2 = Ca(C_{18}H_{35}O_2)_2 + Na_2CO_3$$
$$\text{or} \quad CaSO_4 + 2NaC_{18}H_{35}O_2 = Ca(C_{18}H_{35}O_2)_2 + Na_2SO_4$$

Temporary Hardness.—It is supposed that free carbonic acid in water converts insoluble calcium and magnesium carbonates into soluble bicarbonates. Boiling drives the free carbonic acid out, and the insoluble carbonates are precipitated.

Permanent Hardness.—This is produced by calcium, magnesium, or other salts not carbonates dissolved in water Calcium sulphate (gypsum) and magnesium chlorid may be precipitated by heating the water under pressure to about 150° C. = 300° F., nearly.

Determination of Hardness in Water.—The hardness of water is expressed in degrees as follows:

Degree Clark, or Degree Wanklin means one grain of carbonate of lime in one gallon, or in 70,000 grains of pure water.

Degree Frankland is one gramme of carbonate of lime in 100 litres of water at 4° C = 39° F, or one grain or part of carbonate of lime in 100,000 grains or parts of pure water

One part of calcium carbonate contained in one million

parts of water is equivalent to one milligramme of carbonate of lime, $CaCO_3$, in one kilogramme (one litre) of pure water, and is equal to 0.1 degree Frankland

1 degree Frankland = 0 7 degree Clark;

1 degree Clark = 1.43 degree Frankland.

47a. SUBSTANCES IN SOLUTION IN WATER.

Water of rivers and streams contains, besides suspended vegetable and mineral matter, various mineral substances in solution, generally in small quantities only Spring and well water contains such soluble substances generallly in greater variety and in larger quantities.

The finely divided earthy, silicious, aluminous, and vegetable matter suspended in running water can be removed by filtering, separated by settling and precipitated with part of the soluble matter by boiling

Chemically pure water can only be obtained by careful distillation

Rain water, which is next to it in purity contains various gases in solution. At ordinary temperature and normal atmospheric pressure, 1 volume of rain water can dissolve 1 vol. of carbonic acid.

Solubility of Some Gases in Pure Water.—At 60° F = 15.55° C. and normal atmospheric pressure:

100 volumes of water dissolve	100	volumes	carbonic acid.
" " " " "	2.4	"	" oxid.
" " " " "	1.8	"	air
" " " " "	2.9	"	oxygen.
" " " " "	1.9	"	hydrogen.
" " " " "	1.5	"	nitrogen.

At 0° C 1 volume of water dissolves 1148 volumes ammonia.

The substances more generally found in natural waters are:

1 **Carbonate of Lime**, commonly known as chalk, limestone, marble, and expressed by the chemical formula $CaCO_3$, dissolves only sparingly 3 or 4 parts in 100,000 parts of pure water, and becomes nearly totally insoluble at a temperature of about 150° C = 300° F

If the water contains free carbonic acid in solution, then

2. **Bicarbonate of Lime** is formed, $CaO2(CO_2)$, which is dissolved in considerable quantities. At 77° C = 170° F one half of the carbonic acid is expelled, and the carbonate of lime is precipitated.

3 **Sulphate of Lime or Gypsum.**—$CaSO_4$. Its solubility is dependent on the temperature and on the presence of other soluble matter, especially sodium chlorid or common salt in the water as follows:

Temperature		Solubility		Sodium-chlorid Solution at 65° F. = 18° C.		
Deg. F	Deg. C.	Grains per Gallon	Grammes per Litre	Specific Gravity	Grains per Gallon	Grammes per Litre
32	0	143	2 04	1 014	301	4.3
68	20	168	2 4	1.034	423	6.04
95	35	178	2 54	1 113	301	4.3
212	100	152	2 17			
300	149	0	0			

When water holding sulphate of lime in solution is brought in contact with vegetable matter, the sulphate is reduced gradually to calcium sulphid, and hydrogen sulphid gas is liberated

4 **Chlorid of Calcium,** $CaCl_2$—It is very soluble and its solubility increases with the temperature: One pound of pure water at ordinary temperature dissolves about four pounds of calcium chlorid

5. **Nitrate of Lime,** $CaNO_6$, rarely occurs and its presence is only of importance when the water contains sulphate of soda or magnesia, in which case sulphate of lime will be formed and precipitated. It is a very soluble substance.

6 **Carbonate of Magnesia,** $MgCO_3$, known as magnesite in mineralogy, is sparingly soluble in water about 3 to 4 parts in 100,000 of pure water. Is precipitated by heating to about 150° C = 300° F, nearly.

7 **Sulphate of Magnesia,** $MgSO_4$, known as epsom salt, is very soluble Three pounds can be dissolved in 10 pounds of pure cold water, the solubility increasing with rise in temperature.

8. **Chlorid of Magnesium,** $MgCl_2$.—Is very soluble; 3 pounds dissolve in 1 pound of pure cold water At high temperature, if in contact with iron, decomposes and corrodes the iron.

9 **Carbonate of Iron,** $FeCO_3$.—In water holding carbonic acid in solution it is transformed into bicarbonate, which is dissolved. By exposure to air the carbonic acid is replaced by oxygen and the iron precipitated as hydrated oxid, which is insoluble in water.

10 **Silicic Acid, Silica,** SiO_2.—This substance is deposited by water of hot springs, in which it is present in solution as hydrated silica, sometimes in very considerable quantity.

It is only rarely met with in cold water which will not dissolve more than 0.3 to 0.4 parts in 100,000 parts or ¼ grain per gallon. It is generally in combination with alumina.

11 **Chlorid of Sodium,** NaCl **(Kitchen Salt).**—

100 parts water at 55.4° F., 13° C. dissolve 35.8 parts;
" " " " 228° F., 109° C " 40.4 "

Its solubility seems to increase slightly and gradually with an increase of temperature. Considerable quantities of this salt are dissolved in sea-water and in salt lakes.

Composition of Sea-Water and of Boiler Incrustations, or Scale from It.

(V. B. LEWES.)

	Sea-water		Scale Per Cent
	Grains per Gallon	Grammes per Litre	
Chlorid of sodium	1850.0	26.430	2.79
Chlorid of magnesium	220.5	3.15	——
Hydrate of magnesia	——	——	3.39
Sulphate of magnesia	124.8	1.783	——
Carbonate of magnesia	trace	——	——
Carbonate of lime	3.9	0.55	0.97
Sulphate of lime	93.1	1.33	85.53
Silica	8.4	0.12	1.1
Oxid of iron	trace	——	0.32
Moisture	——	——	5.9
			100

47b. VOLUMETRIC TESTING FOR HARDNESS OF WATER.

Water which contains in solution various proportions of the carbonates, sulphates, or chlorids mentioned, has the

property to convert soluble soap into an insoluble compound, an earthy soap, forming generally a scum or curd without producing lather

When testing water for hardness with soap solution, if it is desired to express such hardness in degrees Clark or Wanklin 70 c.c are taken, because 70 c c contain as many milligrammes as a gallon contains grains, 70,000

If it is desired to express the hardness in degree Frankland, then 100 c.c. is taken as the volume of water to be tested.

Standard or Normal Test Solutions.—All solutions are standardized from a saturated lime solution, prepared as follows:

Saturated Lime water.—Slake with distilled water 2 ounces, or about 57 grammes, of quicklime, let cool, then mix with 1 quart, or about 1 litre, of distilled water in a large bottle, shake well several times, let settle in well-stoppered bottle, then filter the clear liquid through clean filter-paper; use the liquid freshly made at a temperature of 60° F. = 15 55° C.

Soap Solution.—In a mixture of 1 litre, or about 2 pints, methylated spirit and ½ litre, or about 1 pint, distilled water dissolve 10 grammes, or less than ⅓ ounce, of fine cut castile or mottled soap. Keep cool and let stand for a few hours, shaking at intervals; then filter and keep in stoppered bottle.

One-fiftieth Normal Sulphuric Acid Solution, $\frac{N}{50}H_2SO_4$—1 gramme strongest concentrated sulphuric acid, 1020 grammes distilled water

Pour the acid in the water and keep the solution in a glass bottle and not in a stoneware jar

Indicator Solutions.—For coloring lime water purple pink, dissolve 1 gramme = 15 grains phenolphthalein in 0.5 litre = 1 pint of methylated spirit

For coloring lemon-yellow, dissolve 0 5 gramme = 7 grains of methyl-orange in 0 5 litre = 1 pint of distilled water. The change of color from lemon-yellow into orange or pink can only be well distinguished in daylight

Standardizing Solutions.—All solutions are standardized by a saturated solution of quicklime, the solubility of which varies with the temperature of the distilled water as follows:

Temperature		Quicklime, CaO		Hydrated Lime, $CaOH_2O$		Carbonate of Lime	
Deg. F	Deg. C	Grains per Gallon	Grammes per Litre	Grains per Gallon	Grammes per Litre	Grains per Gallon	Grammes per Litre
32	0	80	1.143	106	1 514	142.85	2.04
60	15 55	70	1	92 8	1 326	125	1.7857
212	100	40 5	0 58	53 6	0 7657	72.32	1.033

The saturated lime solution for standardizing should be freshly prepared and used at about 60° F = 15 55° C, when it will contain 70 grains per gallon or 1 gramme of quicklime, CaO, per litre of solution

The one-fiftieth normal sulphuric acid solution is standardized by gradually adding the last portion of distilled water until 10 c.c neutralize exactly 5 6 c c of freshly prepared saturated lime solution, using as indicator a drop of phenolphthalein solution The purple pink color of the indicator in the lime solution will instantly become colorless by a trace of acidity. The $\frac{N}{50}$ standard sulphuric acid solution will neutralize 0 56 milligramme of caustic lime for 1 c.c of acid used, which is equivalent to neutralizing 1 milligramme of carbonate of lime.

Preparation of Water of Standard Hardness.—Neutralize with freshly prepared saturated lime solution 10 c.c. of standard one-fiftieth normal sulphuric acid solution Add to an equivalent quantity of lime solution distilled water to make the volume 70 c.c for the production of water of Clark's 10° hardness, or bring the volume to 100 c c for water of Frankland's 10° hardness=Clark's 7°

Standardizing Soap Solution.—When one centimetre cube of standard soap solution is shaken up with water containing 1 milligramme of carbonate of lime in solution, then the lather formed will not persist over five minutes If the lather disappears in less than five minutes, then the soap solution should be made stronger; if the lather should persist more than five minutes, then the soap solution should be diluted with the mixture of distilled water and methylic spirit.

1 In standardizing soap solutions for determinations of hardness in Clark degrees, 70 c.c of water of 10 degrees Clark standard hardness should be used, and for determinations in

Frankland degrees the 70 c.c. should be diluted with distilled water to 100 c c. To this quantity of water of standard hardness, in a bottle of at least double capacity, add gradually 10 c.c of the soap solution; shake briskly If the lather formed persists for five minutes and not longer, then the soap solution is of standard strength. If lather forms before all of the 10 c c of soap solution have been added, then the latter should gradually be diluted with the mixture of methylic spirit and distilled water If more than 10 c c should be required to form lather then the soap solution should be strengthened.

2 Standardizing soap solution independent of temperature of lime solution: Dissolve in chemically pure (c p) hydrochloric acid, HCl, exactly 1 gramme of pure calcium carbonate, $CaCO_3$ neutralize with a slight excess of ammonium hydrate, NH_3H_2O, and dilute to 1 litre with freshly distilled water

Place 10 c c of this solution in a glass-stoppered bottle of about 250 c c capacity and dilute with distilled water to 100 c c capacity; add gradually the soap solution in small portions, shaking after each addition, until a lather forms which will persist five minutes. Note the number of c.c of soap solutions employed.

Add in very small portions the same soap solution gradually to 100 c c of pure distilled water containing no calcium salt in solution. Shake after each addition and note the number of c c of soap solution necessary to form lather which will persist five minutes Deduct this number from the number of c c of soap solution used with the calcium salt solution, and the number so obtained divided in the 10 milligrammes of $CaCO_3$ will give the number of milligrammes of carbonate of lime per c c of soap solution

Sampling of Water.—Samples of water for testing should be put into absolutely clean glass vessels or bottles No earthenware, stoneware, or metal vessel should be used for this purpose.

Spring and well waters often contain substances which by exposure to the air are separated and produce turbidity or cloudiness. Such waters should be tested as quickly as possible. The water may originally be quite clear, but will become turbid with iron oxid if it contains bicarbonate of iron, and in some cases may become nearly black. If the water con-

tains an excess of bicarbonate of lime and of free carbonic acid, by exposure to air it will gradually loose the excess of carbonic acid and a proportional amount of carbonate of lime or chalk will be precipitated.

Water of rivers and streams having organic matter in suspension, may be decomposed after a few days, especially if sulphates in solution are present in the water Sulphates of lime, of magnesia, or of soda are liable to be changed into carbonates by the organic matter, and into the very bad smelling gas, sulphid of hydrogen, which will be liberated.

Testing Water with Soap Solution for Hardness.—Measure out from the sample of water to be tested, 70 c.c. for determination in Clark degrees and 100 c c for Frankland degrees. Put this quantity in a clean glass bottle of from 2 to 3 times the capacity of the volume of water to be tested. From a divided burette containing the standardized soap solution add gradually a small portion of the latter to the measured sample of water; shake after each addition. When the bubbles which may form break up and disappear quickly, an addition of a little soap solution is made, the shaking repeated, and the behavior of the bubbles observed. When finally the lather thus produced persists for four or five minutes without breaking up, the test may be considered as ended. The number of c c. of soap solution used then indicate the degree of hardness in the water This number gives approximately the number of milligrammes of carbonate of lime or of its chemical equivalent of other soap-destroying substances in solution, producing hardness in water

Special Observations.—When lime only is present the reaction with the soap solution seems to take place instantly; but when magnesia accompanies the lime in about equal proportion, a profuse lather may form, which will, however, disappear in two or three minutes, and several c.c. of soap solution may be added until a persistent lather is formed.

Some experimenters have found that magnesia destroys more soap than lime. In the presence of uncertainty it is well to make several tests with the same water. and if the presence of magnesia is suspected to dilute a sample of water to be tested with distilled water, when it will be found when magnesia is present that the diluted water will show a higher degree of hardness than the undiluted water.

To determine the hardness due to salts of magnesia, shake up 70 c c or 100 c c of the water to be tested with a little ammonium oxalate, and after filtering off the precipitated calcium oxalate treat the filtrate with soap solution

Water containing vegetable matter has a tendency to froth, while water containing free carbonic acid will destroy a certain portion of soap. Freshly distilled water in quantity will freely lather with 1 c.c of soap solution, but will not do so after standing for a little while or after blowing in the bottle. It probably has absorbed a minute quantity of carbonic acid from the air. For this reason distilled water should be freshly made or reboiled for use in such determinations

When the water to be tested shows over 20 milligrammes per litre in hardness, it is advisable to take only one half the quantity and make up the other half with distilled water. The number expressing the hardness in degrees so obtained must in this case be doubled

47c. THE PURIFICATION OF NATURAL WATER.

For Domestic and Industrial Use.

Natural settlement and decantation is employed principally for river-water holding in suspension earthy and organic matter. The suspended impurities which cannot wholly be removed by settlement are in many cases separated by filtration through layers of sand or through specially constructed filters.

Natural settlement and filtration may be assisted by processes for softening water, which will simultaneously remove in many cases the greatest part of the matter in solution.

Clark's or the Lime Process consists in adding to water containing bicarbonate of lime and bicarbonate of magnesia in solution, the proper proportion of caustic lime solution, converting the soluble bicarbonates into insoluble monocarbonates, which separate and settle in a comparatively short time when the layer of water is shallow.

The reactions are indicated by the formulas

$$(1)\ CaO2CO_2 + CaH_2O_2 = 2CaCO_3 + H_2O$$

$$(2)\ MgO2CO_2 + CaH_2O_2 = MgCO_3 + CaCO_3 + H_2O$$

another reaction with bicarbonates of magnesia,

$$(3)\ MgO2CO_2 + 2CaH_2O_2 = MgH_2O_2 + 2CaCO_3 + H_2O$$

producing hydrate of magnesia, which is also insoluble.

When sulphate of magnesia is present in the water, although the magnesia is precipitated as hydrate, some lime remains in solution as sulphate; but the water is nevertheless somewhat improved, as gypsum is only sparingly soluble. The reaction is indicated by the formula

$$(4)\ MgSO_4 + CaH_2O_2 = MgH_2O_2 + CaSO_4$$

The Soda, Process.—Waters containing sulphate of lime or sulphate of magnesia in solution, with little or no carbonic acid, are treated with a solution of carbonate of soda, converting the sulphates of lime and magnesia into insoluble carbonates and the soda into sulphate, which remains in solution. In the case of magnesia the reaction needs heat for completion.

$$(5)\ CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$
$$(6)\ MgSO_4 + Na_2CO_3 = MgCO_3 + Na_2SO_4$$

When free carbonic acid is present the lime or magnesia remain in solution as bicarbonates

$$(7)\ CaSO_4 + CO_2 + Na_2CO_3 = CaO2CO_2 + Na_2SO_4$$

By heating, one half of the carbonic acid is driven off, and the monocarbonates of lime or magnesia are precipitated.

When **caustic soda** (hydrated sodium oxid) is employed, the action is more energetic, and desirable results are often obtained without heat, even when free carbonic acid is present.

$$(8)\ CaSO_4 + CO_2 + 2NaHO = CaCO_3 + H_2O + Na_2SO_4$$
$$(9)\ Ca2CO_2 + CaSO_4 + 2NaHO = 2CaCO_3 + Na_2SO_4 + H_2O.$$

For water containing, in addition to sulphates, carbonic acid or bicarbonates in excess, the combined **Lime and Soda Process** can be applied, adding the necessary soda solution to reduce the sulphates and lime solution for the remaining carbonic acid and bicarbonates.

$$(10)\ CaO2CO_2 + CO_2 + CaSO_4 + CaH_2O_2 + 2NaHO = 3CaCO_3 + Na_2SO_4 + 2H_2O$$

$$(11)\ 2(CaO2CO_2) + CaSO_4 + CaH_2O_2 + 2NaHO = 4CaCO_3 + Na_2SO_4 + 2H_2O$$

and when sulphate of magnesia is present,

$$(12)\ CaO2CO_2 + CO_2 + MgSO_4 + 2CaH_2O_2 + 2NaHO = 3CaCO_3 + MgH_2O_2 + Na_2SO_4 + 2H_2O$$

Bicarbonate of iron behaves similar to bicarbonate of magnesia, and the chlorids and nitrates of lime and magnesia are treated like the sulphates.

Remarks.—The quicklime for lime solution should be made with carbonate of lime or limestone as free as possible of foreign matter. The lime should be well slaked in just sufficient water to be converted into a very strong milk of lime, which after this should be well stirred in a considerable bulk of water. After settlement of the surplus lime, the clear lime-water only, without particles of suspended lime, should be used. By slaking the quicklime, CaO is converted into hydrate of lime, CaH_2O_2, the latter being in reality only soluble in water. (See Table of Solubility.)

Caustic Soda or Hydrate of Soda, NaHO.

The Commercial Grades are as Follows:

(All soluble in hot water.)

Commercial Name	Sodium							Insoluble	Water
	Hydrate	Carbonate	Aluminate	Silicate	Sulphite	Sulphate	Chlorid		
Caustic bottoms.	58.6	—	5 6	0 7	0 2	5 5	6 1	23	—
Vat-liquor cream.	74 6	1 4	1 3	0.2	0 1	2 2	7 8	—	12 3
Red liquor cream.	75	3 1	0 8	2 1	1 5	1 5	6.8	0 2	9 0
60 per cent white.	79 8	1 1	0 4	0.1	—	3 6	15.1	—	—
70 per cent white caustic..	89 6	2 4	0 2	0 3	—	3.4	3 9	—	—
High strength.	96	0 2	0 2	0 1	—	1.5	1.3	—	—

Make a nearly concentrated solution of the caustic soda. Take for water-softening preferably 70 per cent white caustic and pour this solution in the quantity of water required. Stir up and let settle, drawing the clear solution for use. Unpainted iron vessels with well made joints should be used for this purpose.

(See page 230 for carbonate of soda)

Sulphate of Alumina Hydrated, $Al_2O_3(SO_3)_3+18H_2O$, contains 51.35 per cent pure sulphate of alumina and 48.65 water in 100 parts.

Soluble in cold and hot water It is mainly used for clarifying water, but it does not improve the quality for any purpose, as the bicarbonate of lime in the water is converted into sulphate of lime, which is one of the most undesirable ingredients in water for any purpose.

Sulphate of Iron, the Ferrous Sulphate (green vitriol), $FeSO_4+7H_2O$, soluble in cold water as well as the ferric sulphate, Fe_2SO_6, soluble in hot water, have been occasionally used for clarifying water, especially polluted waste waters.

Carbonate of Soda, Na_2OCO_2

Commercially Manufactured as Follows:

Commercial Name	Chemical Formula	Per Cent Sodium					Dissolves in Water
		Carbonate	Hydrate	Sulphate	Chlorid	Water	
Soda-ash (impure).....	Na_2CO_3	60 to 70	—	—	—	—	hot
Soda crystals (wash soda) ...	$Na_2CO_3+10H_2O$	34.22	0.1	2 54	0.27	62.84	cold
Soda crystal carbonate	$Na_2CO_3+H_2O$	82.9	0	tr.	tr.	17	hot
Concentrated crystal soda.	$2Na_2O.3CO_2$	70	—	—	—	—	cold
Pure alkali.......	Na_2OCO_2	92.22	0	0 14	0.5	0	hot

Water treated in this manner is liable to retain some iron, which unfits it for quite a number of uses.

While lime water and soda solutions may be mixed together for use, when sulphate of alumina or of iron is employed with the former, the solutions should be kept separate until they are actually added to the water to be treated.

In the **alum process of filtration,** in which a small quantity of alum, $K_2SO_4+Al_2O_3(SO_3)_3+24H_2O$, from 3 to 6 milligrammes per litre, or the equivalent quantity of aluminium sulphate, $Al_2O_3(SO_3)_3+18H_2O$, is employed, the filtering operation is performed in closed vessels under pressure, the rate of filtration being greatly increased.

The jelly-like precipitation of the aluminium hydrate, which forms in this process, clears the water and retains the bacteria in the filtering material. But the carbonate of lime is thereby transformed into sulphate of lime, or temporary hardness into permanent hardness of the water, and in the case of alum, potassium carbonate remains in dissolution in the water.

In the **iron process of purification** metallic iron is agitated with the water in a specially constructed revolving iron drum, then exposed to the oxidizing action of air and filtered through sand.

Distillation is the only process to obtain absolutely pure water. In the U. S. Navy, water aerated during distillation and run through a bone-black filter for the purpose of improving its taste, is exclusively used for drinking purposes.

Solubility of Various Substances in Water.

Substance	Per Gallon				Per Litre	
	At 60° F.		At 212° F.		15.5°C.	100° C.
	Lbs.	Grs.	Lbs.	Grs.	Grms.	Grms.
Alum (potash-alum)	0 95	—	35 7	—	95	3570
Aluminium sulphate	3.3	—	8.9	—	330	890
Calcium carbonate [1]	—	2 5		1.5	0 035	0.021
" chlorid	40		∞ [4]		4000	∞
" hydrate	—	93	—	53.6	1 33	0.766
" nitrate	40	—	∞	—	4000	∞
" oxid	—	70	—	40.5	1	0 58
" sulphate [2]	—	161	—	152	2 3	2.17
Magnesium carbonate	—	—	—	1.5	—	0.021
" chlorid [3]	20	—	40	—	2000	4000
" hydrate	—	2	—	2	0 03	0.03
" oxid	—	1.4	—	1.4	0 02	0.02
" sulphate	3	—	13	—	300	1300
Sodium biborate (borax)	0.4	—	5.5	—	40	550
" carbonate (dry)	1.2	—	4 5	—	120	450
" " crystals	4.1	—	14	—	410	1400
" chlorid	3.5	—	4	—	350	400
" hydrate	6 1	—	∞	—	610	∞
" hyposulphite	5	—	20	—	500	2000
" sulphite	2.5	—	10	—	250	1000
" sulphate	1.1	—	4.2	—	110	420

[1] Insoluble 290° F.
[2] Insoluble 300° F.
[3] Insoluble 302° F.
[4] ∞ = unlimited.

Water for Steam Boilers. — Such water should be as free as possible from substances forming hard incrustations or scales, and from corroding acidity before entering the boilers.

Water containing principally bicarbonate of lime in solution, when heated to near the boiling-point in a feed-water heater, will lose half of the carbonic acid. The carbonate of lime and the suspended matter will precipitate and may be blown out of a properly constructed apparatus. If, however, sulphate of lime is in solution, only a small part will separate by the elevation of the temperature to the boiling-point. Such feed-water must be heated to about 300° F., 149° C.,

before entering the boiler, when the incrustation will almost wholly form in the pre-heating apparatus, which must be so constructed that the scales can be easily removed.

Water for Manufacturing

And Technical Purposes.

Where washing and rinsing operations have to be performed it is desirable to obtain as pure a supply of water as possible

In such cases the water-softening processes indicated above may be of practical application

For a great many manufacturing operations and processes a certain hardness of the water is not objectionable.

47d. Water for Domestic Use.—Water containing bicarbonate of lime is not considered objectionable, and only water containing other ingredients and especially sulphates of lime and magnesia should be avoided Sulphate of magnesia, or epsom salt, is extensively used in medicine as a purgative and although natural waters contain a relatively small proportion of this salt, they are, nevertheless, on that account objectionable

A certain amount of sodium chlorid may not in itself be very objectionable in such water, but it becomes highly objectionable when a strong suspicion exists that the salt has reached the water by infiltration of sewage from the vicinity

Water containing organic matter, vegetable or animal, is generally contaminated by bacteria, which, although in some cases harmless, may in other cases produce sickness and death, caused by typhus and cholera germs.

The chemical examination of water relative to its adaptability for domestic use is therefore mainly directed to the determination of nitrogenous organic matter in the water.

The presence of nitrogenous organic substances is manifested by:

1 **Free Ammonia**, which, as the product of putrefaction of nitrogenous organic matter, is dissolved in contaminated water. It is distilled out of a measured quantity of such water. The presence of free ammonia in water is not necessarily a sign of contamination; it may be in dissolution in uncontaminated water

2 **Albuminoid Ammonia.**—As derived from contaminated water, does not exist originally in the water The term has its origin from the fact that when "albumen" dissolved in water is decomposed by a strongly alkaline solution of potassic permanganate added thereto, ammonia can be distilled out of this compound After free ammonia has been distilled from contaminated water, the nitrogenous matter yet in the water is decomposed by the addition of an alkaline solution of potassic permanganate, resulting in the production of a second quantity of ammonia which will be liberated by distillation as before.

3 **Nitrites** derive their existence from nitrogen in organic matter which, combining with dissolved oxygen to nitrous acid, forms, with dissolved mineral substances, nitrites

4 **Nitrates** are the result of a more complete oxidation of nitrogen to nitric acid, combining with mineral oxids to nitrates

The presence of both nitrites and nitrates in water are indicative of contamination, the nitrates more particularly of animal than of vegetable source.

5. **Required Oxygen.**—This is the oxygen necessary for the complete oxidation of the organic matter contained in contaminated water

Bacteria is a microscopical living organism which thrives and multiplies by feeding on nitrogenous organic impurities in water.

Miquel, a French bacteriologist, after 15 years' experience classifies water, according to its contents of bacteria, per centimetre cube as follows:

Excessive pure water.	0 to 10
Very pure........................	10 " 100
Pure..............................	100 " 1000
Medium.	1000 " 10000
Impure..	10000 " 100000
Very impure above	100000

Boiling for ½ hour will remove 99 per cent of bacterial life; the remainder is entirely harmless.

Absolute sterility can only be attained by heating the water for 45 minutes under pressure to 115° C.

AVERAGE CONDITION OF WATER

From Various Sources.

STANDARDS FOR UNPOLLUTED WATER (1 TO 5).

(Parts per million or milligrammes in 1 kilogramme (litre).)

Designation	Total Solids	Hardness.	Chlorn	Nitrogen in Nitrites and Nitrates	Authority
1. Rain	29.5	3	8.22	0.03	Rivers' pollution
2 Upland surface	96.7	54	11.3	0.09	Commission of
3. Deep well.	432 8	250	51 1	4.95	Great Britain
4. Spring	282	185	24 9	3.83	do.
5. American rivers	150-200	50-150	3-10		A. R. Leeds
6 Safe limit	300 [1]		50 [2]		[1] Dr. Smart, [2] Frankland
7. To be condemned	1000				Dr. Smart
8. Sewage			110-160		
9. Human urine			5872		

47c. Solutions for Determination of Chlorin, Ammonia, and Organic Matter.—All reagents for water analysis should be kept in bottles with ground caps covering the ground-glass stoppers.

Standard Silver Nitrate Solution for chlorin determination:

(1) Chemically pure crystallized silver nitrate. 4.8022 grammes.
Distilled water to make the solution..... 1 litre.

Each c.c. of this solution added to a solution of a chlorid will precipitate silver chlorid containing 1 mlgrm. of chlorin.

(2) **Sodium Carbonate,** chemically pure......... 50 grammes.
Distilled water............................. 300 c.c.

(3) **Indicator.**—Potassium chromate, pure....... 2 gr.
Distilled water.......................... 100 c.c.

Determination.—To 100 c c of the water to be examined in a white porcelain casserole or dish, add 1 c c potassium chromate solution, producing a distinct yellow color; then introduce gradually, from a measuring-burette, silver solution until the yellow changes into a red tint The number of c c of silver solution added gives the number of mlgrms of chlorin in the 100 c c. of water and 10 times this number those in a litre of water or the parts of chlorin in million parts of water.

When it is found necessary to operate on larger quantities,

then 1 c.c. of carbonate of sodium solution is added to 1 litre of the water under examination in a white porcelain casserole evaporated to 100 c.c. and titrated as above.

Should the water contain coloring-matter, which would interfere with the color observation, then freshly precipitated aluminium hydrate should be shaken up with the water After filtering, measure out the litre to be examined. The coloring-matter will have been removed.

Nitrogen in Nitrite.

(4)	Sulphanilic acid	1 gramme.
	Distilled water, hot.	100 c.c.
(5)	Naphthylamine hydrochlorid	½ gramme.
	Distilled water	100 c.c.

Boil for ten minutes, keeping volume constant. Add pulverized carbon when in glass-stoppered bottle and filter when required for use

Standard Solution of Sodium Nitrite.—(6) Add to a solution of commercial sodium or potassium nitrite a solution of silver nitrate as long as a precipitate is formed. Decant and wash two times with cold water Dissolve in boiling water and concentrate. Crystallize from the hot solution and dry the silver nitrite crystal in the dark.

Of dry silver nitrite so obtained, dissolve 0 22 gramme in hot distilled water, add a slight excess of sodium chlorid, cool, and dilute to 1 litre After the precipitate of silver chlorid has settled, decant 5 c c. of clear solution, which should be made up to 1 litre with distilled water This standard solution of sodium nitrite contains in each c c. 0.0001 milligramme of nitrogen.

Determination.—To 100 c c of the water under examination in a *Nessler* jar add successively 1 c c. of sulphanilic acid solution and 1 c c. of naphthylamine hydrochlorid solution, cover with watch-glass and let it stand for ½ hour, during which prepare a number of "Nessler" jars by putting in each a known quantity, but different in each jar, of the sodic nitrite standard solution, dilute with pure distilled water to 100 c c and add to each jar 1 c c. of sulphanilic acid and 1 c c of naphthylamine hydrochlorid solution. At the end of the 30 minutes compare the pink color of the water to be examined with that

of the known sodic nitrite solution, and the nitrogen contents of the latter solution of the same depth of color as the water examined will indicate the nitrogen as nitrite contained in the water

Nitrogen in Nitrates.

Standard solutions.

Phenol-sulphonic Acid.

(7)	Sulphuric acid, pure concentrated	148 c.c.
	Phenol, pure	24 grammes.
	Distilled water..........................	12 c.c.
(8)	**Potassium Nitrate** solution:	
	Potassium nitrate, KNO_3, pure..........	0.7221 gramme
	Distilled water.........................	1 litre

Dilute with distilled water 100 c c of this solution to 1 litre, then each c c of this dilute solution will contain 0.01 milligramme of nitrogen as nitrate.

(9) **Sodium Chlorid** solution:

Sodium chlorid, pure (from metallic sodium)..	1.6497 grammes
Distilled water.........................	1 litre.

1 c.c will contain 1 milligramme of chlorin

Determination.—Add to 100 c c. of water under examination ½ c.c of sodium carbonate solution (2).

Evaporate to dryness on a water-bath. Add to the dry residue 2 c.c. phenol-sulphonic acid (7) and then ammonium hydrate in excess (about 15 c.c). Dilute with distilled water to 100 c.c in a "Nessler" jar, compare the color with the color of a number of similar jars prepared in the same manner with various but known quantities of standard nitrate solution. To each of the standard nitrate-solution jars should be added sodium chlorid solution, corresponding to the chlorin contents of the water under examination, previously determined.

Free and Albuminoid Ammonia.

(Standard reagents.)

10. **"Nessler's" Solution:**

(a)	Mercuric chlorid, pure $HgCl_2$, 16 grammes dissolved in distilled water	0.5 litre.
(b)	Potassic iodid, KI.	35 grammes.
	Distilled water..........................	200 c.c.

Pour the *a* in the *b* solution until a slight excess is indicated To this compound add solid potassium hydrate, KOH, 160 grammes, and dilute to 1 litre with distilled water. Then from a strong solution of mercuric chlorid, add very gradually until the red mercuric iodid begins to be permanent. Let the precipitate settle. This reagent should have a pale straw color and will improve by age.

A trace of ammonia or of ammonium salts will produce in this solution a distinct brownish-yellow coloration. If the quantity of ammonia is sensible, a brown precipitate will be produced

(11) **Alkaline Potassic Permanganate.**

Solid potassic hydrate, KOH	200 grammes.
Potassic permanganate, $K_2Mn_2O_8$ . .	8 "
Distilled water....................	1250 c.c

Boil down to 1 litre and keep for use.

(12) **Ammonia Solution** (for standardizing).

Ammonium chlorid pure dry..............	1.5706 grammes.
Distilled water...	500 c.c., ½ litre.

5 c.c of this solution diluted to 500 c.c. represents 0.01 milligramme of ammonia, NH_3, per c.c. of the diluted solution.

Water for this analysis should be specially distilled and the first 100 c.c. rejected, and each successive 50 c. c. of distillate should be tested with the addition of 2 c c of Nessler solution in a Nessler jar, until by looking through solution lengthways at a white sheet of paper no change in color appears after a lapse of 5 minutes.

Determination of Free Ammonia.—Add to 200 c.c. of pure water 10 c c of sodic carbonate solution, in a tubulated glass retort connected to a Liebig condenser of large size. The neck of the retort should project 3 or 4 cm in the condensing-tube and a tight joint made with large rubber tubing. Distil about every 15 minutes 50 c.c. into a **Nessler Jar** until 100 c.c of distillate have been obtained. Test the second jar of 50 c.c. by adding 2 c c. of *Nessler solution*, so as to be sure that no ammonia is present

Now add to the contents of the retort 500 c c or ½ litre of the water to be examined. Distil into each Nessler jar 50 c c until 4 jars are filled, which is generally sufficient. Add to

each successive jarful 2 c c of "Nessler" solution until no ammonia reaction is apparent after 5 minutes.

Measure in a number of *Nessler jars* various known quantities of standard ammonia solution, dilute each with pure distilled water to 50 c.c., add to each, 2 c.c. of *Nessler solution*, and compare the coloration with that of the jars containing the distillate of the water under examination.

Suppose 7 c c of standard ammonia solution diluted to 50 c c will match in color the first jar of Nesslerized distillate, 2 c c the second jar and ½ c.c the third, then, since each c.c of standard ammonia solution contains 0 01 milligramme of ammonia, we have for the quantity of ammonia in the original ½ litre, $0\ 07+0\ 02+0\ 005=0\ 095$ milligrammes, or 0.19 milligrammes per litre of water examined.

Determination of Albuminoid Ammonia.—Mix 200 c.c. of pure water and 50 c c of alkaline permanganate solution (11) in a clean retort connected as above to a condenser. Distil 3 *Nessler* jars full each of 50 c c. To insure freedom from ammonia add the 2 c c. of Nessler solution to the third. Then add 500 c c , ½ litre, of the water under examination to the contents of the retort Distil 50 c c jars off, add to each jar obtained 2 c c of Nessler solution, until no change of color takes place, or until it may become unsafe to continue the distillation Compare as before with standard ammonia solutions. The result will give the contents in the sum of free and albuminoid ammonia Subtract from this the previously obtained result for free ammonia

Determination

Oxygen-consuming Capacity or Required Oxygen.

Standard Solutions.

Dilute strong sulphuric acid, 1 part, in 3 parts distilled water.

Potassic Permanganate Solution.

Potassic permanganate, pure	0.3952 grammes.
Distilled water	1 litre.

Each c.c of this solution contains 0.1 milligramme of available oxygen

Oxalic Acid Solution.

Crystallized oxalic acid, $H_2C_2O_4 2H_2O$.	0.7875 grammes.
Distilled water	1 litre

10 c.c. of this oxalic acid solution diluted to 200 c.c. with pure

water and 10 c.c. of dilute sulphuric acid (1 acid to 3 of distilled water) should be titrated while boiling, with the standard potassic permanganate solution and the required amount of the latter recorded

Mix in a porcelain casserole 200 c c of water to be examined, and 10 c.c of dilute sulphuric acid, and add from a burette the standard permanganate solution until the color of the water is of a decided red. While boiling for ten minutes add gradually permanganate solution to maintain the exact color of the start. Suppress the flame and then add 10 c c. or more of the oxalic acid solution, to destroy the color. Restore the solution to a faint pink color by the gradual addition of the permanganate solution

From the total permanganate solution employed should be deducted the quantity added for the 10 c.c. of oxalic acid solution The remainder will indicate the available oxygen at the rate of 0 1 milligramme per c.c of permanganate solution necessary for the consumption of the organic matter in the water.

If nitrites, ferrous salt, or hydrogen sulphids should be present, the necessary correction should be made.

471. FILTERING OF WATER SUPPLY FOR CITIES.

Material, Thickness of Beds, Rate of Filtration.

Location		Fine Sand, Inches	Coarse Sand, Inches	Fine Gravel, Inches	Medium Gravel, Inches	Coarse Gravel, Inches	Small Stone, Inches	Large Stone, Inches	Total Thickness, Inches	Gals. per Sq. Ft. per Day Filt'ed	Vertical Inches per Hour
Berlin		22	2	6	5	3	4	12	54	74	5
Zurich		32	6	4	—	6	—	—	48	200	14
Hague		12	10	—	—	10	—	6	38		
Warsaw		24	—	2	—	3	12	11	52		
Hudson, N. Y		6	18	6	6	6	6	24	72		
London	Chelsea	54	—	[1]3	39	—	—	—	96	50	3 3
	Lambeth	36	—	[1]12	—	36	—	—	84	62	4 1
	Southwark	36	12	9	—	9	—	—	66	43	2 7
	W. Middlesex	27	12	—	—	27	—	—	66	38	2 5
	East London									39	2 5
	Grand Junction									59	4
Poughkeepsie, N Y.		24	—	—	18	—	6	24	72		
Liverpool										60	4
Stuttgart										49	3 3
Altona										60	4

[1] Top layer, fine sand. Shells. Bottom, gravel or large stone.

Effects of Filtration.—Numerous investigations have shown that filters in good condition will remove not only suspended mineral matter from the water, but that an average of over 98 per cent of the bacteria originally contained in the water remain in the filter, and that no disease-producing germs, as typhoid-fever germs and cholera germs, pass through it.

A filter, however, becomes only effective for the removal of bacteria and disease germs from the water, after the sand grains from the top to a certain depth have been covered by a gelatinous substance in which subsequently most of the organic matter in the water is caught and retained.

The accumulation of this slimy matter on the top layer reduces the filtering capacity This layer, of about ½ inch thickness, must, therefore, be removed from time to time, say every three or four weeks in summer and at intervals of one and one-half to two months or more in winter.

When the thickness of the filtering-bed has been reduced to a certain extent, then new sand, or the old sand thoroughly washed, should be replaced on the bed.

Rivers.

Drainage and Sedimentation.

River	Drainage Area, Square Miles	Mean Annual Discharge, Cu. Ft. per Second	Sedimentation		
			Annual Tons	Height of of a Col. of 1 Sq. Mile Base, Feet.	Depth Over Drainage Area; Inches
Mississippi	1,214,000	610,000	406,250,000	291 2	0 00288
Rio Grande	30,000	1,700	3,830,000	2.8	0 00110
Potomac	11,043	20,160	5,557,250	4	0.0043
Uruguay	150,000	150,000	14,780,520	10.6	0 00085
Rhone	34,800	65,850	36,000,000	31.1	0.01071
Po	27,100	62,200	67,000,000	59	0.01139
Danube	320,300	315,000	108,000,000	93.2	0.00354
Nile	1,100,000	113,000	54,000,000	38.8	0.00042
Irrawaddy	125,000	475,000	219,430,000	209	0.02005

The data given in the foregoing and in the following table must be considered only as very rough approximations. The low water consumption in European cities may be explained by the continued use of the old-established wells.

Population and Consumption of Water in American and European Cities.

City	Population	Daily Consumption per Capita, Gallons	City	Population	Daily Consumption per Capita, Gallons
New York, N. Y.	1,900,000	92	Hartford, Conn.	62,000	125
Chicago, Ill	1,800,000	131	Saginaw, Mich.	60,000	100
Philadelphia, Pa.	1,200,000	143	New Bedford, Mass	55,000	99
Brooklyn, N. Y.	1,000,000	100	Manchester, N. H.	51,000	50
St. Louis, Mo.	574,569	75	Birmingham, Ala	50,000	160
Boston, Mass.	558,400	92	Covington, Ky	50,000	62
Pittsburg, Pa.	366,000	220	Springfield, Mass.	49,300	87
Buffalo, N. Y.	300,000	217	Harrisburg, Pa.	45,000	130
Cincinnati, Ohio.	300,000	124	Augusta, Ga.	40,000	106
Detroit, Mich.	257,000	140	Sioux City, Iowa.	40,000	43
Milwaukee, Wis.	250,000	105	Holyoke, Mass.	40,000	77
Washington, D. C.	230,000	177	Binghampton, N. Y.	38,000	
Louisville, Ky.	200,000	80			
Toronto, Ont.	188,000	100	Paris, France.	2,400,000	20
Omaha, Neb.	180,000		London, England.	4,140,000	44
St Paul, Minn.	150,000		Hamburg, Germany.	583,700	58
Providence, R. I.	150,000	60	Altona, "	156,500	56
Rochester, N. Y.	147,700	48	Basel, Switzerland.	74,500	35
Indianapolis, Ind.	115,000	74	Berlin, Germany	1,606,430	16
Allegheny, Pa.	105,000	247	Breslau, "	335,000	22
Atlanta, Ga.	106,000	164	Chemnitz, "	139, 70	12
Toledo, Ohio.	100,000	70	Cologne, "	255,000	45
Albany, N. Y.	98,000	162	Dresden, "	280,000	22
Grand Rapids, Mich.	90,000	88	Frankfort, "	186,000	36
Richmond, Va.	90,000	151	Hanover, "	189,980	18
New H ven, Conn.	90,000	130	Karlsruhe, "	74,200	28
Fall Ri er, Mass.	87,780	28	Konigsberg, "	162,000	17
Lowell, Mass.	87,000	75	Munich, "	298,000	34
Dayton, Ohio.	76,000	53	Stettin, "	118,000	32
Des Moines, Iowa.	70,000	43	Stuttgart, "	139,000	21
Los Angeles, Cal.	70,000	200	Wiesbaden, "	66,000	21
Charleston, S. C.	64,000	22	Zurich, Switzerland.	96,700	57

MINERAL OILS.

48. Condensers for Mineral Oil.

Square feet of condensing surface per gallon of oil distilled per hour Heavy oil 1 sq. ft., burning oil $1\frac{1}{4}$ sq. ft, naphtha $1\frac{3}{4}$ sq. ft, gasoline 2 sq. ft.

Internal area of condensing pipe in sq. inches per gallon of oil distilled in 1 hour should be not less than 0.05 sq. inch.

If d = internal diameter of pipe in inches;

N = number of gallons of oil to be distilled per hour, then

$$d=\sqrt{\frac{0.05\times N}{0.7854}} \text{ or nearly } \frac{\sqrt{N}}{4}.$$

Products of Shale or Coal Distillation.

Commercial Name	Sp. Gr. of Water, 1000	B, Boiling-point. M, Melting-point		Latent Heat of Vaporization		Vapor Density	Specific Heat
		Deg. C.	Deg. F	Deg.C. per Kgm. Water	Deg. F. per Lb Water		
			B				
Gasoline.	642	21	70		100 2		0.5800
Naphtha.	720	46	115		100.6	3.005	0 5687
"	756	80	175		133.5	3.190	0.5104
Burning oil. . .	810	127	260		105.4	4.270	0 4991
Intermediate oil	843		545			7 770	0.4950
Lubricating-oil.	865						0.4492
"	890		M				0.4441
Paraffin wax . .			118				0.4164
" " .			130				0.3659
Stearine.			128				0.3529

Quantity of Water Needed for Distillation of Oils.

If N = number of gallons of oil to be distilled per hour;

g = specific gravity of the distillate;

H = latent heat of vaporization of distillate;

S = specific heat of distillate;

t = initial temperature of water;

T = overflow temperature of water;

n = number of gallons of water of the temperature, t, needed

to distil N gallons of oil per hour and to cool it from its boiling-point b to 60° F.

1 English gallon of water = 10 lbs.

$$10n(T-t) = 10gN \times H + 10gN(b-60)S;$$

$$n = \frac{gN(H+(b-60)S)}{T-t}.$$

Petroleum Products.

Technical Names	Degree, C	Gravity Degree, Baumé	Gravity Specific Water = 1	Uses
	B.[1]			
Cyanogen	0°	110		Manufacture of ice
Rhigolene	18 3	100	0 60	Anæsthetic, medical
Petroleum ether	40–70	80–85	0 65–0 66	Solvent, gas machines and gas stoves
Gasolene	70–90	75–80	0 66–0 69	do.
Naphtha	80–110	70–76	0 69–0 70	Solvent for resins, stoves
Ligroine	80–120	62–67	0 71–0 73	Solvent, lamps
Benzine (deodorized)	120–150	70–76	0 69–0 70	Substitute for turpentine, cleaning
	F.[1]			
Burning oil (kerosene)	43–50			Lamps
Headlight-oil	67			Locomotive headlights
Mineral sperm	149		0.829	
Lubricating-oil (neutral)		32–38		Machinery
" cylinder				Steam cylinders
	M.[1]			
Paraffin, 1st quality	51.6			Candles & various applications
" 2d "	53.3			
" 3rd "	57.3			
" scales	56			
" Rangoon tar	61			Combustibles
" ozokerite	62			

[1] B., Boiling. M., Melting. F., Flashing.

Illuminating Power in Standard Candles of Oils of Various Specific Gravities.

From Light-oil Stills				From Heavy-oil Stills	
Specific Gravity	Standard Candles	Specific Gravity	Standard Candles	Specific Gravity	Standard Candles
716	12.20	794	19 40	801	19 22
764	20 70	798	18 60	805	20.26
768	19 90	804	19 40	814	18.41
774	19 25	811	17 00	818	16 70
779	18 94	816	16 50	823	16.40
784	20.00	818	16 65	830	16 54
791	18 90			835	15 80

Specific Gravities of Molten Paraffins.

Temp.		Melting-points						
Deg. C.	Deg. F.	C = 42.2 F. = 108	45.5 114	49.4 120 5	50 122.25	50.4 122.75	53.5 128.25	56.25 133.25
71	160	770.69	771.93	773 91	770.79	770 23	775.73	777.23
68.5	155	771.19	773.30	775.31	771.49	771.63	776.53	778.53
65.5	150	773.09	774.73	77[illegible] 57	77[illegible] 19	772.83	778.03	780.03
62 8	145	775.09	776.20	777 77	775 19	774.63	7[illegible]9 73	781.53
60	140	776 79	777 63	778 47	776 89	776 33	781.33	783.33
57.2	135	778 99	779.53	781 47	778 69	778 43	783.03	
54 4	130	780 49	781.13	782.67	780.29	779.73		
51.6	125	781 99	783 43	784 41				
48.9	120	783 59	784 73					
46.1	115	785.29						

C. = degree Centigrade. F. = degree Fahrenheit.

Solid Paraffin Waxes.[1]

(Specific Gravity.)

Temp.		Melting-points					
Deg. C.	Deg. F.	°C. 41.1 °F. 106	44.4 111.5	49 4 120 5	50 122.25	52 125.75	55 131
15.5	60	875.25	882.30	898 95	901.05	903.5	908.65

[1] S. P. Stadler, Handbook of Industrial Chemistry.

Detection of Mixtures in Mineral Oil.

Wax in Oil.—Cool and press a small quantity of the oil.

Fatty Oil.—Mix about ½ ounce with a saturated solution of caustic soda in absolute alcohol, in a large test-tube, boil for 20 or 30 seconds. The presence of only 2 per cent of fatty oil produces a gelatinous mass on cooling. With a larger percentage the mixture becomes gelatinous and even solid while hot.

For quantitative determination of fatty oil mix 50 grains of the oil to be examined with 500 grains of clean white fine silicious sand, add an excess of alcoholic soda solution, evaporate on a water-bath, with constant stirring, until all alcohol has been expelled; filter and wash with gasoline or other *very volatile solvent* until a drop of the filtrate evaporates on a watch-glass without leaving an oily mark. The soap formed by the fatty oil, attached to the sand grains, remains unaffected

by the volatile solvent; all the mineral oil is in the solution, from which the volatile part is slowly evaporated in a tared flask. By weighing the remaining mineral oil and subtracting its weight from that of the oil treated the quantity of fatty oil in the mixture is obtained.

Rosin.—Rub a small quantity of oil between the palms of the hand and smell.

Water.—Oil finished by an acid and caustic-soda treatment emits a slight crackling sound in burning, which can be heard by applying the ear to the lamp.

Oil finished by distillation does not emit such a sound.

Data of Deep-well or Prospect Borings.

(Drills operated through ropes, Rp.: rods, Rd ; diamond-drills, D.)

Location	Apparatus	Advance in 12 Hours: Average: Exclusive of By work	Advance in 12 Hours: Average: Inclusive of By-work	Advance in 12 Hours: Maximum Feet	Total Depth in Feet	Diameter: Bore: Surface	Diameter: Bore: Bottom	Diameter: Core	Hours of Work: Exclusive of By-work	Hours of Work: By-work	Hours of Work: Total
				'		'	'	"			
Aver. 37 borings.	Rp.		2' 9"		80-1300						
Beyreuth......	"		8 4"		1000	12					
Pennsylvania...	"		70'	100	1500	8	5½				
Sudenberg.....	Rd.	3' 1 8"	2' 5.3"		1290	18			4749	1368	6117
Malkowitz.....	"	3' 4.1"	1' 10.2"	6	1857	24	7		4896	3912	8808
Sperenberg...	"	7'	2' 6"		4170						
English (Hand).	"		1'-15'		500		6	2½			
Rheinfelden (Switzerland).	D.		11' 10"	65	1422	7	3½				1440
Liebau (Silesia).	"		6' 5"		1761	7	3				3288
Bomisbe Brod...	"		4' 10"		2207				3768	1680	5448
Tessenitz.......	"		10'		3978						7 mth.
"	"				1783						5 mth.
Fauvelle.*.....	—		12'		1206		2½				
Michigan.......	D.		8'-60'	60			2½	1⅛			
Schladebach (Germany)...					5760	11	1¾	½			

Normal Hydrocarbons mostly contained in Petroleum.

Atomic weights in chemical formula, C = 12; H = 1.

Chemical Name	Chemical Formula	Degree C. Melting-point	Degree C. Boiling-point	Specific Gravity, Water, 1000	Remarks
Methane........	CH_4				Marsh-gas
Ethane..........	C_2H_6				Gas
Propane......	C_3H_8		−17		Gas
Butane	C_4H_{10}		1		
Pentane........	C_5H_{12}		37–39		
Hexane	C_6H_{14}		71		
Heptane........	C_7H_{16}		99		Ligroine
Octane..........	C_8H_{18}		125	718	
Nonane..	C_9H_{20}	−51	149 5	733	Sp. gr. at 0° C.
Decane..........	$C_{10}H_{22}$	−32	173	746	Kerosenes
Undecane.......	$C_{11}H_{24}$	−26 5	194 5	774	
Dodecane	$C_{12}H_{26}$	−12	214	775	
Tridecane	$C_{13}H_{28}$	− 6 2	234	775	
Tetradecane	$C_{14}H_{30}$	+ 4 5	252 5	775	
Pentadecane	$C_{15}H_{32}$	10	270 5	775	
Hexadecane	$C_{16}H_{34}$	18	287	775	
Heptadecane ..	$C_{17}H_{36}$	22 5	303	776	Sp. gr. at melting-points
Octdecane.	$C_{18}H_{38}$	28	317	776	
Nondecane... .	$C_{19}H_{40}$	32	330	777	Solid paraffins at ordinary temperature
Eicosane	$C_{20}H_{42}$	36 7	205	777	
Docosane, etc. ..	$C_{22}H_{46}$	44.4	224.5	778	
Untriacontane ...	$C_{31}H_{64}$	68	302	780	
Pentatriacontane.	$C_{35}H_{72}$	74 7	331	781	

49. COMPRESSED GASES.

Compressed Air.

Pressure Absolute, Lbs per Sq. Inch	Volume Air = 100 at 60° F. One Atmosphere	Temperature of Compressed Air		Pressure Absolute, Lbs. per Sq. Inch	Volume Air = 100 at 60° F. One Atmosphere	Temperature of Compressed Air		Pressure Absolute, Lbs per Sq Inch	Volume Air = 100 at 60° F. One Atmosphere	Temperature of Compressed Air	
		Deg. F	Deg. C.			Deg. F.	Deg C			Deg. F.	Deg. C.
14.7	100	60	15.5	70	33.02	357	181.29	250	13.38	772	411.57
15	98.58	63	17 26	75	31 44	375	190 49	300	11.75	788	420.34
20	80 36	108	42 60	80	30 03	391	199 26	400	9.58	896	480.76
25	68 59	149	64 76	85	28.77	405	207 66	500	8.17	986	530.00
30	60.27	180	82 10	90	27 62	418	214.71	600	7 18	1065	574.00
35	54 01	208	98.38	95	26.58	434	223.25	700	6 44	11 7	603.74
40	49 13	237	113 86	100	25 63	447	230 91	800	5 86	1200	648.80
45	45.18	259	126 54	125	21 88	508	264.66	900	5 39	1256	680.00
50	41.93	282	138.96	150	19 22	561	293.91	1000	5 00	1310	710.00
55	39 19	303	150 53	175	17 23	608	319 87	2000	3.06	1706	930.0
60	36 84	322	161 38	200	15 67	649	343 31				
65	34 80	340	171 61	225	14 41	687	364 71				

Note Gases found to exist in air after having been subjected to great pressure and at very low temperatures· *Helium, Argon, Kripton, Neon, Metargon, Etherion.*

Ammonia.

(From table by De Volson Wood.)

Temperature		Pressure Absolute		Heat of Vaporization or Latent		Volume of Vapor		Volume of Liquid	
Deg. F.	Deg. C.	Lbs. per Sq. In.	Klgm. per Sq. Cm.	B.T.U. Lbs. per Deg. F.	Metric T.U. Klgm. Deg. C.	Per Lb. in Cubic Feet	Per Klgm. in Litres	Per Lb. in Cubic Feet	Per Klgm. in Litres
−30	−34.44	14.13	0 993	524 84	132.26	18.67	1165.66	0 0237	1.480
−25	−31.67	16.17	1.137	521 52	131 41	16.42	1025.18	0 0238	1 486
−20	−28.89	18.45	1.297	518 23	130.59	14.48	904 06	0.0240	1 498
−15	−26.11	20 99	1 476	514 90	129 75	12.81	799.79	0 0242	1 511
−10	−23.33	23.77	1.671	511.66	128 94	11 36	709.26	0 0243	1.517
− 5	−20.55	27.57	1 938	508 12	128 05	9 89	617 48	0 0244	1 523
0	−17.78	30.37	2 135	504 12	127 04	9.14	570 65	0.0246	1 536
5	−15	34 17	2.402	501 59	126 40	8 04	501.98	0 0247	1 541
10	−12.22	38 55	2 710	498 22	125 55	7.20	449.53	0 0249	1.555
15	− 9.44	42.93	3.018	494 93	124 72	6 46	403 33	0 0250	1 561
20	− 6.67	47 95	3 371	91 50	123 86	5 82	363 36	0 0252	1 573
25	− 3.89	53 43	3.756	488 22	123 02	5 24	327 16	0.0253	1 580
30	− 1.11	59 41	4.177	484 9	122.19	4 73	205.32	0 0254	1 586
35	1.67	65 93	4 635	481 56	121 35	4.28	267.22	0 0256	1 598
40	4.44	73	5.132	478 21	120 51	3.88	242.25	0 0257	1 605
45	7.22	80.66	5 670	474 77	119.89	3 53	220.39	0 0260	1.623
50	10	88.96	6 254	471 44	118.80	3.21	206.42	0 0261	1 629
55	12.78	97.93	6.884	46 .01	117.94	2 93	182 93	0 0263	1 642
60	15.5	107.60	7.564	464 76	117.12	2 67	166.70	0.0265	1.654
65	18.33	118.03	8.297	461 82	116 38	2 45	152.96	0.0266	1.661
70	21.11	129 21	9 084	457 95	115.40	2.24	139 75	0 0268	1 073
75	23.89	141.25	9.930	454 70	114.58	2.05	127 99	0 0270	1 680
80	26.67	154.11	10.834	450.75	113.59	1.89	118 00	0 0272	1 698
85	29.44	167.86	11.800	447 75	112.83	1.74	108.64	0.0273	1 704
90	32.22	182.80	12 851	443 70	111.81	1.61	100 52	0.0274	1 711
95	35	198.37	13.945	440 95	111.12	1.48	92 30	0 0276	1 723
100	37.78	215 14	15.123	437.35	110 21	1 36	84.91	0.0277	1.729

Liquid Gases.

Substance	Critical Temperature, Degrees C.	Critical Pressure, Atmospheres	Boiling-point		Freezing-point, Degrees C.	Color of Liquid	Authority
			at Atmospheres	Degree C.			
Acetone	+237.5	60	1	+ 56.5	—	Colorless	Sajotschewski
Acetylene	+ 37.5	68	1	− 85	—	"	Ansdell
Air	−140	39	1	−191.4	—	"	Olszewski
"	—	—	4	−176	—	—	"
"	—	—	14	−146	—	—	"
"	—	—	0	−205	—	—	"
Alcohol	+243 6	62.7	1	+ 78 3	−130	"	Ramsay
Ammonia	+130	115	1	− 33.7	− 75	"	Dewar
Argon	−121	50.6	1	−187	−189.6	"	Olszewski
Carbon dioxid	+31	75	1	− 78	− 65	"	Andrews
Carbon monoxid	−141	36	1	−190	−207	"	Wroblewski
Chlorin	+141	83.9	1	− 36.6	−102	Yellow	Dewar
Cyanogen	+124	61.7	1	− 21	−34.4	Colorless	"
Ethylene (olefiant-gas)	+ 10.1	51	1	−102 5	−169	"	"
Hydrochloric acid	+ 51.25	86	1	− 35	−116	"	Ansdell
Hydrogen	−234.5	20	1	−243.5	—	"	Olszewski
"	—		10	−239.7	—	"	"
Methane	− 73.5	56 8	1	−160	—	"	Wroblewski
Nitrogen	−145.5	39.2	1	−194.3	−214	"	Olszewski
Oxygen	−118.8	50.8	1	−184	—	Pale blue	Wroblewski
"	—	—	22	−138.5	—	—	"
"	—	—	27	−129.6	—	—	"
"	—	—	50	−113	—	—	"
Ozone	—	—	1	−106	—	Indigo blue	Olszewski

Critical Temperature: The temperature above which the gas cannot be compressed into a liquid.
Critical Pressure: The lowest pressure under which a gas at the critical temperature can be converted into a liquid.

The freezing-point of carbon dioxide should probably be −1C5 and not −65. (Author.)

Temperature of Liquefied Gases Evaporating Under Various Pressures.

Pressure		Boiling-points in Degrees C					
Atmospheres	Centimetres. Mercury	Air	Oxygen	Nitrogen	Carbon Monoxide	Carbonic Acid	Ethylene or Olefiant Gas
50	—	—	−113		—		
39	—	−140	—	—	—	0	
35	—	—	—	−146	—	− 4	
27	—	—	−129.6	—	—	−12	− 17.75
24.4	—	—	−133.4	—	—	−16	− 20.6
22.2	—	—	−138.8	—	—	−18	− 24.4
17	—	—	—	−160	—	−26	− 32
14	—	−146	—	—	—	−34	− 38
4	—	−176	—	—	—	−64	− 77
1	76	−191.4	−184	−194.4	−190	−78	−102.5
	75	—	—	—	−	—	−103
	73.5	—	—	—	−190		
	74	—	—	−193			
	16	—	—	− −	−197.5		
	12	—	—	−201			
	10.7	—	—	—	...	—	−115.5
	10	—	—	—	−198.8		
	8	—	—	−201.7			
	6	—	−	−204	−201.5		
	4	—	—	−206	−201.6		
	3.1	—	—	—	—	—	−139
	0.98	—	—	—	—	—	−150.4
	0	−205	—	−213			

Note.—The second column indicates the barometric pressure.

50. EXPLOSIVES.

Gunpowder.—Berthold Schwartz of Freiberg is said to have invented gunpowder in 1328. Explosives, however, have been known by the Chinese at least since the beginning of the Christian Era, and the Arabs have used an explosive mixture similar to gunpowder long before its invention by the Franciscan friar, Schwartz, in Germany.

Composition of Gunpowder.

In per cent parts.

	English	French			
		Hunters	War	Mining	
Saltpeter..............	74.07	78	75	65	62
Charcoal...............	14.82	12	12.5	15	18
Sulphur................	11.11	10	12.5	20	20

Fulminate of Mercury.—Prepared as follows: To the dissolution of 1 part of mercury in 12 parts of nitric acid add 11 parts of alcohol, 86 per cent strong, and bring to ebullition on a sand-bath. As soon as the mixture starts boiling, remove from the fire, but let the reaction continue for some time. When action has ceased, the fulminate will be found precipitated. Dilute with water and filter, wash until no acid reaction is apparent; collect the little crystals of yellowish-white fulminate, and mix it on a marble slab with $\frac{1}{10}$ its weight of saltpetre by means of a wooden spatula, forming in this manner a paste, which is distributed in proper proportion in percussion-caps, and dried. Is exploded by shock or by heat.

Nitroglycerin, $C_3H_5N_3O_9$.—It was first produced in Pelouze's laboratory in Paris in 1847 by the Italian chemist Sobrero.

Alfred Nobel, a Swedish engineer, devised methods for its manufacture in 1860.

Preparation —1 part glycerin is poured in a mixture of 2 parts nitric acid of 1.525 specific gravity and 4 parts of concentrated sulphuric acid of 1 83 sp. gr., keeping the temperature below 25° C. = 77° F. Wash the nitroglycerin in water, being careful to remove all traces of acidity. Let the heavy oily nitroglycerin settle Remove and dry carefully.

At ordinary temperatures nitroglycerin is a colorless or yellowish oily liquid of 1.6 specific gravity, insoluble in water but soluble in ether, wood spirit or methylic alcohol, benzol, chloroform, and hot alcohol.

It solidifies or freezes at various temperatures depending on the mode of manufacture and the purity of ingredients used, between 12.8° C. and 20° C. (Nobel's at 12.8° C, Mowbray's at 7 2° C., Champion's at 20° C.)

1 volume of nitroglycerin produces from 1300 to 1500 volumes of gases at 100° C, but this is expanded about 8 times by the heat produced by an explosion, the temperature of the gases reaching nearly 2600° C.

Nitroglycerin in a liquid state will not explode by a gradually increasing pressure. A blow from a hammer will detonate the portion struck without affecting the remainder.

When frozen or solid a blow or violent shaking may determine the explosion of the whole mass.

The detonation of gunpowder, of guncotton, or of fulminate will cause nitroglycerin confined or otherwise to explode.

Heat necessary to explode it in a closed space, 257° C

Nitrogelatine or Gelatinized Nitroglycerin.—Invented by Nobel and patented Oct. 13th, 1876, in England. Consists principally in a solution of soluble pyroxylene, soluble gun-cotton, or collodion cotton in nitroglycerin, with the addition of a few per cent of acid, ethers, or other solvents, or only by the aid of gentle heat applied to the nitroglycerin.

The explosive jelly so formed can be pressed into cartridges, and its explosive sensibility modified by the addition of other substances such as camphor, which renders the nitrogelatin more or less insensible to blows

Nitrogelatine is a transparent elastic substance of a pale yellow color, of a density of 1 6; can be cut with a knife, but softens a little without becoming greasy when heated to 50°-60° C (122°-140° F.)

Dynamite.—Nitroglycerin absorbed in a porous substance, more especially silicious infusorial earth known under the name of "kieselguhr" in Hanover, Germany.

Colonia Dynamite.—Nitroglycerin 35 per cent and mealed gunpowder.

Hercules Dynamite.—Nitroglycerin 35 per cent and mealed gunpowder.

Vulcan Dynamite—Nitroglycerin 40 per cent and mealed gunpowder.

Seranine Dynamite.—Nitroglycerin and chlorate of potash.

Horsley's Powder—Nitroglycerin and chlorate of potash.

Dualine.—Nitroglycerin saltpetre and sawdust.

Lithofracteur.—Nitroglycerin, 55; kieselguhr, 21; charcoal, 6; barium nitrate, and bicarbonate of soda or either of them, 15; sulphur and manganese oxid or either of them, 3 per cent

Ammonia Powder.—Nitroglycerin 14 to 20; nitrate of ammonium 8; charcoal 6 parts by weight. Being hygroscopic, its maximum effect is only produced when freshly prepared.

Giant Powder, No. 2—Nitroglycerin, 40; saltpetre, 40; resin, 6; sulphur, 6; infusorial earth, 8 per cent.

Sebastin.—Nitroglycerin, saltpetre and a specially prepared charcoal.

Brain's Powder.—Nitroglycerin, chlorate of potash, and, as an absorbent, any carbonaceous material as coal dust, sugar, starch, etc.

Rhenish Dynamite.—Solution of 2 to 3 per cent of naphthalin

in nitroglycerin, 70; chalk, 3; heavy spar, 7; kieselguhr, 20 per cent.

Forcite.—Nitroglycerin and gelatinized cellulose of a thin consistency, when combined as a blasting gelatin, is mixed with a mixture of nitrate of soda coated with sulphur and wood tar, with the addition of about 1 per cent of wood pulp. The cellulose or cotton is gelatinized by heating in water under pressure. Nitrated cellulose mixed with some oxidizing salt is also sometimes used.

The grades are:

Forcite gelatin.—Nitroglycerin 95, cellulose 5 per cent.

Forcite No. 1.—Nitroglycerin 75, explosive base 25 per cent.

Forcite No. 3.—Nitroglycerin 40, explosive base, 60 per cent.

Forcite No. 3*A*.—Nitroglycerin 30, explosive base 70 per cent.

Atlas Powder.—Nitroglycerin from 20 to 75 per cent, according to grade, wood fibre, nitrate of soda and from 2 to 3 per cent of carbonate of magnesia.

Gelatine Dynamite.—Blasting gelatine with saltpetre and wood pulp containing from 80 to 60 per cent of nitroglycerin.

Glukodine.—A saturated solution of cane sugar in glycerin produces by nitration a compound, when white and liquid, of about 33 parts of nitroglycerin and 3.2 parts of nitrosaccharose and when black 30.2 parts nitroglycerin and 4 parts nitrosaccharose.

This is mixed with guncotton in the first case and charcoal in the second.

American Hercules Powder.	No. 1	No. 2
Nitroglycerin	75.00	40
Saltpetre (potassic nitrate)	2.1	31
Chlorate of potash	1.05	3.35
Carbonate of magnesia	20.85	10
White sugar	1	15.66

Judson Powder.—Oxidizing salts (nitrates) are made non-absorbent by coating them with a varnish of a hydrocarbon, solid at ordinary temperatures. To this, 10 per cent gritty anthracite is added and the whole mixed with 5 to 6 per cent of nitroglycerin.

Paleine or Straw Dynamite.—Nitroglycerin mixed with nitrocellulose made from straw.

Trautzel's Dynamite.—Nitroglycerin 75 parts, guncotton pulp 25 parts, charcoal 2 parts.

Carbo Dynamite.—Nitroglycerin about 90 per cent, carbon about 10 per cent.

Snider Explosive.—Nitroglycerin 94 and a mixture of collodion, guncotton, camphor, and ether, 6 per cent.

Von Dahmen's Safety Dynamite—Claims an addition to nitroglycerin preventing its freezing at low temperatures.

Smolianinoff Explosive.—Adds to about 80 per cent of nitroglycerin a fluid, kept secret. It is claimed that the compound when charged in a shell can withstand the shock of a discharge from a gun.

Guncotton.—**Braconnet of Nancy** (France) discovered in 1832 that when concentrated nitric acid acted on starch, fibres, and similar substances, highly combustible materials were produced.

Pelouze, in 1838, found that cotton, paper, and other vegetable substances could be treated in this manner, that the compounds thus produced could be ignited at a temperature of about 180° C = 356° F. produced by a sudden pressure or a blow.

Schoenbein, of Bale, Switzerland, in 1845 manufactured guncotton by treating cotton with a mixture of concentrated nitric and sulphuric acids. He is, therefore, generally considered to be the inventor of what is called "guncotton" in English, "schiesbaumwolle" in German, "fulmicoton" or "Pyroxile" in French, from which the generic name of "pyroxiline" is derived.

Lenk's Process.—For the manufacture of guncotton, 1 part of nitric acid, sp. gr. 1.5, not less than 1.48, 3 parts sulphuric acid, sp. gr. 1.84, are mixed by flowing in thin streams in an earthen vessel and cooled before use.

Cotton spun in loose threads and in skeins of 85 grms. in weight each, is hung on hooks and immersed for 2 or 3 minutes in a boiling weak solution of potash, 1.02 sp. gr., wrung out or centrifugated, washed thoroughly in cold water, and thoroughly dried.

A number of dried skeins are immersed for a few minutes in a tall cast-iron vessel in about 230 to 300 times their weight of the mixture of acids, and then placed on a grating over a vessel into which the superfluous acid drips from the cotton, which is at the same time slightly compressed. In this con-

dition the cotton is nearly 10 times heavier as originally and is placed in a stone jar, in which it is left for 24 hours, well covered, preventing access of air, and kept at a temperature between 5° and 25° C The crude guncotton is wrung out or centrifugated in order to free it from acid as much as possible, then washed in water and sometimes left in running water for several weeks, treated with a weak boiling solution of potash, washed in water again, and then dried in air at a temperature of not over 25° C = 77° F.

Loose cotton or corded cotton can be treated in a similar way Sometimes the nitrated cotton is finally immersed in a sodium silicate solution for a short time and afterward exposed to the action of the air for several days, then again washed in running water and dried at a temperature of not more than 35° C = 95° F.

Guncotton can be distinguished from ordinary cotton by the harsh feeling and by its strong electric attraction after having been rubbed between the fingers in moderate heat. When not confined or compressed it explodes, by the application of heat or by ignition, with a brilliant flame and a hissing sound, without a loud report. A blow from a hammer will only explode the part which has been struck.

In a moist state, after having been compressed from pulp in a hydraulic press, it contains about 15 per cent water; it may be perforated by a red hot iron, or drilled into or sawed without exploding.

By means of a detonator composed of a percussion-cap with fulminate of mercury and a variable amount of well dried and compressed guncotton, it has been exploded while containing as much as 17 per cent of water.

One gramme (0.035 oz. avoir.) of guncotton produces about 585 cub. cm. of gas at 0° C. = 32° F. and at ordinary barometric pressure of 760 mm. = 29.92 inches.

Heat developed by explosion is estimated to be about 4500° C = 8132° F., producing a pressure of 15,300 atmospheres.

Guncotton is insoluble and is not affected by water. It can be kept in a wet state without decomposing for years, and is perfectly safe to handle in this condition.

Schultze's Gunpowder.—Wood pulp purified from resinous and fatty matter, dried and treated with acids, then finely ground and waterproofed.

Lanoy's White Powder.—Nitrated wood or sawdust, 22 parts; sodium nitrate, 65 parts; sulphur, 13 parts.

Uchatius' White Powder.—Potato starch, 1 part; nitric acid fuming, 8 parts. Keep the mixture cool, and pour the thick fluid in a thin stream into 16 parts concentrated sulphuric acid, under constant stirring. Let the resulting jelly stand for 12 hours and wash repeatedly and alternately with pure water and soda solution; dry the white powder at a temperature of 50° to 60° C. = 112° to 140° F. Strongly hygroscopic and very rending when exploded.

Tonite.—Guncotton finely divided and nitrate of baryta; about the same weight of each.

Totten's Gunpowder.—Grains of a nitrated material with an inside kernel of pure guncotton.

E. C. Powder.—Nitrocellulose, part soluble and part insoluble in ether, 47 to 56 parts; cellulose unconverted, 3 to 4 parts; nitrates of potassium and barium, 38 parts.

Johnson Powder.—Nitrocellulose, 50 parts; saltpetre, 22 to to 40 parts; barium nitrate, 0 to 25 parts; torrefied starch and lampblack, 3 to 10 parts.

Nitromannite.—Dissolve manna sugar, 1 part, in nitric acid, 4 parts, add sulphuric acid until no more precipitate is formed, filter, wash precipitate, and dry at 40° C = 104° F.

When pure, forms white acicular (needle-shaped) crystals, soluble in ether and hot alcohol. Its explosive qualities are similar to those of fulminate of mercury.

Collodion Cotton.—Although not properly an explosive, it nevertheless enters in the composition of nitrogelatin: Pulverized saltpetre, 20 parts; sulphuric acid of sp. gr. 1.835, 31 parts; cotton, 1 part Dissolve saltpetre in acid, keeping cool, then add cotton, let stand 24 hours at a temperature of about 30° C. = 86° F., wash with cold water, then with warm water, and dry.

Flameless Explosives.—Explosives in which the flame is suppressed or quenched at the moment of explosion.

Roburite, by Dr. Carl Roth.—A mixture of two solid substances, neither being an explosive, and becoming such only when intimately mixed: chlorinated dinitrobenzol and ammonium nitrate, according to the formula $C_6H_3Cl(NO_2)_2 + 9NH_4NO_3$.

Bellite, by Carl Lamm.—Melt di or trinitrobenzol at a temperature of 80° to 90° C. = 176° to 194° F. and mix nitrate

of ammonia in it so that the grains of the latter will be covered by the nitrobenzol

Securite.—About 20 parts of meta-dinitrobenzol and 74 parts of saltpetre or ammonium nitrate

Favier's Explosive.—Saltpeter (potassium nitrate) or ammonium nitrate is coated with a molten hydrocarbon like paraffin and formed into a hollow cylindrical cartridge the interior of which is filled with a nitrated explosive, such as guncotton, picric acid, chlorate of ammonia or of potash, the last two having been previously covered with an easily fusible hydrocarbon. The explosive compound is moulded into cylinders so as to fill the hollow of the cartridge and is inserted when needed. It is exploded by a detonator of gun-cotton or potassic chlorate of about $\frac{1}{10}$ its weight and a fulminate cap

Hellhoffite.—Nitropetroleum or nitrotar oils and nitric acid, placed in separate vessels so that they can automatically mix when desired to explode.

Romite.—Nitrate of ammonia and naphthaline or nitronaphthaline are to be mixed, and when required for use chlorate of potash is to be added

Nitrate of ammonia coated with paraffin or naphthaline, and for use mixed with chlorate of potash.

Rack-a-rock.—Compressed cartridges of chlorate of potash are impregnated just before use with a mixture of dead oil or other liquid hydrocarbon and bisulphid of carbon. Nitrobenzol or a mixture thereof with picric acid may also be used.

Panclastite, by Eugene Turpin.—Liquid nitric peroxid and bisulphid of carbon, $2CS_2+3N_2O_4$:

	N1	N2
Chlorate of potash.	80	40
Coal-tar.	14 to 16	15
Wood charcoal.	4 " 6	40
Nitrate of potash.		40

Granulated or in compressed cartridges.

Picric Acid.—By dropping melted phenol into boiling nitric acid, trinitrophenol, $C_6H_2(NO_2)_3OH$, is obtained, called carbazotic acid or picric acid, also produced by treating phenol or carbolic acid, C_6H_5OH, with a mixture of nitric and sulphuric acid

Melenite, by Eugene Turpin.—Picric acid compressed and cast, picric acid agglomerated with an aqueous solution of gum

arabic, picric acid combined with fatty bodies, heavy oils, etc., picric acid and a 3 to 5 per cent collodion solution in ether and alcohol. Picric acid in dry powder is primed by 1.5 grammes of fulminate of mercury. Cast or agglomerated, a detonator of picric acid in powder primed by fulminate is employed.

Similar compounds are known under the names **Liddite** in England, **Ecrasite** in Austria, **Thorite** in United States.

51. STRENGTH OF MATERIALS.

Definitions and Explanations of Technical Terms.

Stress.—The force tending to produce a physical change of form in material.

Strain.—The change of form produced by a stress.

Tensile Stress.—The force which acts by pulling apart.

Tensile Strength, Modulus of Strength or Modulus of Tenacity.—The number of pounds necessary to produce rupture on a square inch of the material by pulling apart. The number of kilogrammes producing rupture at a section of 1 square centimetre of the material by pulling apart.

Compressive Stress.—The force which acts by pressure.

Compressive Strength, Crushing Strength. Modulus of Crushing Resistance, Coefficient of Crushing Resistance.—The number of pounds necessary to crush the material of 1 square inch of cross-section. The number of kilogrammes which will crush the material at a section of 1 square centimetre.

Ultimate Strength.—The force expressed in units of weight producing rupture when acting on unit of area of the material.

Dead Load.—A permanent or staying load.

Moving Load or Live Load.—A temporary load, which comes and goes or which may be applied and removed.

Elasticity.—Is the property of material to resume its original form after the removal of a distorting stress.

Limit of Elasticity.—The stress in units of weight acting on unit of area, which if increased would begin to produce a permanent set or deformation in the material.

Modulus of Elasticity or Coefficient of Elasticity.—The stress in units of weight acting on unit of area which would shorten or lengthen any material an amount equal to its original length under the assumption that its elasticity would remain perfect within these limits.

IRON AND STEEL.

Ultimate Tensile Strength.

Elastic limit about 60%.

	Boiler Plate				Best Flange		Bessemer Steel		Chain Iron		Tank Iron	
	Best		High Grade									
	Pounds per Square Inch	Klgms. per Square Centimetre	Pounds per Square Inch	Klgms. per Square Centimetre	Pounds per Square Inch	Klgms per Square Centimetre	Pounds per Square Inch	Klgms. per Square Centimetre	Pounds per Square Inch	Klgms. per Square Centimetre	Pounds per Square Inch	Klgms. per Square Centimetre
Highest....	64,000	4.710	57 000	4,000	53,300	3,750	86,600	6,090	59,900	4,200	53,200	3,740
Lowest.. ..	55,300	3.887	51,800	3,640	33,000	2,320	74,500	5,230	46,300	3,250	36,100	2,535
Average...	58,984	4,177	54,100	3,800	42,140	2,960	83,600	5,870	53,100	3,720	43,800	3,070

	Ingot Iron		Ingot Steel				Chrome Steel		Steel Castings		Cast Iron	
	Carbon 0.01 to 0.13		Carbon 0.234 to 0 639		Carbon 0.691 to 1.328		Average Density 7.838		Carbon 0.25 to 0.55		Carbon. Graphitic 1.45 to 2.80; Combined 0.3 to 2.55	
	Pounds per Square Inch	Klgms. per Square Centimetre	Pounds per Square Inch	Klgms per Square Centimetre	Pounds per Square Inch	Klgms per Square Centimetre	Pounds per Square Inch	Klgms. per Square Centimetre	Pounds per Square Inch	Klgms per Square Centimetre	Pounds per Square Inch	Klgms. per Square Centimetre
Highest...	55,000	3,867	94,000	6,643	135,300	9,412	193,000	13,500	105,000	7,370	31,700	2,210
Lowest...	43,000	3,123	60,000	4,218	101,000	7,100	168,500	11,850	68,000	4,750	18,760	1,419
Average ..	50,000	3,548	74,600	5,268	118,300	8,300	180,000	12,700	88,000	6,300	26,400	1,870

Elastic Resilience.—Is the work of resistance at the limit of elasticity. Load × elastic elongation.

Ultimate Resilience.—Is the work of resistance to the production of rupture of the material. Load × total elongation.

Transverse Stress.—The force acting transversely to the length of the material.

Bending Stress.—Force acting by deflecting transversely.

Torsional Stress.—Force acting by twisting the material around.

Shearing Stress.—Forces acting in opposite direction in the same plane transversely on the material.

Compressive or Crushing Strength.

	Cast Iron [1]		Iron and Steel[2] Carbon, 0.14 to 0.76		Wrought Iron[3] Elastic Limit		Steels[3] Elastic Limit	
	Lbs. per Square Inch	Klgms. per Square Centimetre	Lbs. per Square Inch	Klgms. per Square Centimetre	Lbs per Square Inch	Klgms. per Square Centimetre	Lbs. per Square Inch	Klgms. per Square Centimetre
Highest.	167,000	11,700	140,683	9890				
Lowest .	99,770	7,014	67,994	4780				
Average	145,118	10,190	98,042	6900	26,000	1800	50,000	3500

[1] Tests for ordnance.
[2] Bauschinger.
[3] British Steel committee.

Compressive Strength of Stone.

Name of Stone	Tons per Square Feet	Kilogrammes per Square Metre
Granite and sienite.	700 to 1000	7,655,000 to 10,936,000
Basalt and trap.	800	8,749,000
Limestone and marble.	350 to 700	3,827,500 to 7,655,000
Best sandstone.	500	5,468,000
Sandstone, ordinary	350	3,827,000
Slate.	200 to 500	2,187,000 to 5,468,000

Shearing Strength of Iron and Steel.

	Pounds per Square Inch	Klgms. per Square Centimetre	C = per cent carbon in steel	
			Pounds per Square Inch	Klgms. per Square Centimetre
Iron, single shear	41,000	2880		
Iron, double shear	39,000	2740		
Steel.			48,000 + 32,000 C	3374 + 2250 C

51a. WOODS.

Board Measure.

Timber is measured by board measure designated B.M., the unit being 1 sq. foot 1 inch in thickness. For sawed and hewed timber the measurement may be expressed in cub. feet. For round logs the number of cubic feet is determined in accordance with the "Ordnance Manual" as follows:

If L=length in feet, p=mean girth in feet or the circumference at the middle of the log and v=volume or contents in cubic feet, then:

$$v=\left(\frac{p}{4}\right)^2 L=\frac{p^2L}{16}.$$

Strength of Woods.

Woods Used in Buildings and Machines	Tensile per Square Inch 1000 lbs.	Compressive, Sq. Inch, 1000 lbs.	Shearing, Square Inch, 1000 lbs.	Bending Stress on Extreme Fibres, Sq. Inch, 1000 lbs.
Ash	10–15	4–8	6	12
Beech	8–12	8–9	5	9
Birch	7–10	6–10	5–6	9
Box	10–15	8–10		8
Cedar	4–9	4–7	1–3	8
Cherry		5–7	3	
Chestnut	7–12	4–5	1–2	7
Cypress	4–6			
Elm	8–13	8–10		8
Fir	5–10			7
Hickory	10–14	10–14	6–7	
Locust	10–15	7–9	7	12
Lignum vitæ	10–12	8–10		12
Maple	10		6	8
Oak, live	10	8–10	8–9	12
Oak, white	10	6–8	4–5	11
Pine, white	3–8	3–6	2–3	8
Pine, yellow	5–12	6–10	4–6	7
Spruce, fir, deal	4–10	4–6	3	7
Walnut, black	8	5–7	4–5	12
Poplar	3			

Yellow Pine Beams.

Safe Uniformly Distributed Load in Tons of 2000 Pounds.

Span in Feet	Depth in Inches for 2-inch Thickness.					
	4	6	8	10	12	14
6	0.370	0.834	1.482	2 314	3 343	4 538
8	0.278	0.624	1.110	1.736	2 500	3 402
10	0.222	0.5	0.9	1.388	2	2 762
12	0.186	0 416	0 740	1.158	1.666	2 268
14	0.158	0.358	0.634	0.892	1.428	1 944
16	0.138	0.212	0.556	0.868	1 250	1 702
18	0.124	0.278	0.494	0.772	1.114	1 512
20	0.112	0.250	0.444	0.694	1 000	1 362

51b. Formulas for the Determination of Parts in Buildings and Machinery.

Columns or Pillars.

If P = crushing weight in tons of 2240 pounds;
d = thickness of pillar in inches;
l = length of pillar in feet;

then for pillars of from 4 to 30 diameters in length, according to Euler:

For oak $$P = 10.95\frac{d^4}{l^2}$$ and

for red pine $$P = 7.81\frac{d^4}{l^2}$$

According to Gordon:

$$P = \frac{fa}{1 + \frac{l^2}{cd^2}},$$

in which a = the cross-sectional area in square inches of the pillar;

c = coefficient = 188 for timber generally = 250 for dry yellow pine;

f = factor = 7200 for hard timber generally = 5000 for dry yellow pine.

For pillars of more than 30 diameters in length, according Tredgold:

If W = safe load in pounds;

b, t, and d = breadth, thickness, and diameter in inches;

l = length in feet; then

$$W=n\times\frac{d^4}{l^2} \text{ for square;}$$

$$W=n\times\frac{bt^3}{l^2} \text{ for rectangular;}$$

$$W=n\times\frac{d^4}{1\,7l^2} \text{ for circular pillars.}$$

n = factor = 1500 for beech, chestnut, elm, white pine;
n = 2000 for ash, mahogany, etc ;
n = 2500 for teak, oak, and hardwood generally;
n = 2200 for red pine and similar timber

Beams Under a Bending Load.

P = load in pounds applied at any point of a beam;
W = uniformly distributed load in pounds;
l = length of beam in inches between supports;
b = breadth and d = depth of beam in inches;
R = stress in pounds at extreme fibres from Table "Strength of Wood" page 260

Beam firmly fixed at one end with the load P at its free extremity.

$$1 \quad P=\frac{Rbd^2}{6l}$$

Beam firmly fixed at one end with the load W uniformly distributed over the whole length:

$$2 \quad W=\frac{Rbd^2}{3l}$$

Beam supported at both ends loaded by P at the middle:

$$3. \quad P=\frac{2Rbd^2}{3l}$$

Supported at both ends uniformly loaded:

$$4.\quad W=\frac{4Rbd^2}{3l}.$$

Supported at both ends loaded in the middle by P and in addition uniformly loaded by W:

$$5.\quad P=\frac{2Rbd^2}{3l}-\frac{W}{2},$$

$$6.\quad W=\frac{4Rbd^2}{3l}-2P.$$

Firmly fixed at both ends loaded at the middle:

$$7.\quad P=\frac{4Rbd^2}{3l}.$$

Uniformly loaded:

$$8\quad W=\frac{8Rbd^2}{3l}.$$

Relative Transverse Strength of Beams.

Fastened at one end, load suspended from free end	= 1
" " " " uniformly distributed over free length	= 2
Supported at both ends, load at middle	= 4
" " " " uniformly loaded	= 8
Fastened at both ends, loaded in the middle	= 8
" " " " uniformly loaded	=12

Woods.

Physical Properties and Adaptability for Various Purposes.

Elasticity.—Ash, hickory, hazel, lancewood, chestnut, yew, snakewood.

Toughness.—Oak, beech, elm, lignum-vitæ, walnut, hornbeam

Even grain.—For carving and engraving· Maple, walnut, pear, box, lime tree

Durability, for dry works—Cedar, oak, beech, yellow pine chestnut, etc.

For wet construction.—Elm, alder, beech, white oak, planetree white cedar.

Ship building.—Cedar, pine, fir, larch, elm oak, locust, teak.

House building—White pine, yellow pine, oak, ash, spruce, sycamore, etc.

Furniture, common.—Beech, birch, cedar, cherry, pine, poplar, walnut, etc.

Furniture, fine.—Amboyna, black ebony, cherry, mahogany, maple, walnut, oak, rosewood, satinwood, sandalwood, chestnut, cedar, tulipwood, zebrawood.

Machine and millwork; frame.—Ash, beech, birch, elm, oak, pine, poplar, etc

Rollers.—Box, lignum-vitæ, mahogany, etc.

Teeth of gear-wheels—Crabtree, hornbeam, hickory, locust, maple.

Patterns.—Alder, cherry, white pine.

51c. PRESERVATION OF TIMBER.

Wm. Burnett, 1858—**Chlorid of Zinc**, 1 part dissolved in 10 parts water is forced under a pressure of 100 lbs. or 125 lbs. per square inch into the pores of the wood. Cost from $5 to $7 per thousand feet board measure.

Bethell, 1838—Saturating the wood with substances obtained from the distillation of coal tar, especially **creosote or dead oil**, applied under a pressure of 150 lbs. per sq. inch. Each cubic foot of timber absorbs in 12 hours from 8 to 12 lbs of dead oil. Cost of creosoting 1000 feet, board measure, oak, or spruce fir from $5 to $8.

Seely.—Heats the wood in a bath of **creosote** from 212° F. to 250° F. long enough to expel the moisture from the woods The hot oil is then withdrawn and cold oil admitted Absorbtion from 6 lbs. to 12 lbs. per cubic foot; cost about 30 cent. per cubic foot.

Robin—Treats wood with **coal tar** or **oleaginous vapors** in an air-tight chamber from 6 to 12 hours.

Leuchs.—Introduces the wood in an air-tight drum supplied with a steam-jacket; admits steam to the jacket until all moisture is expelled, then admits a solution of **paraffin** under pressure for a certain time, after which the remaining paraffin is withdrawn.

Hayford.—Admits steam to the wood in a closed drum and forces air into it until a pressure of 40 lbs. per sq. inch is attained with a temperature of 250° to 270° F This is continued from 5 to 12 hours, according to size and quality of timber treated. Then a vacuum is produced by an air-pump and the creosote oil is admitted and finally subjected to a pressure of about 75 lbs. per sq. inch for more or less time

Boucherie, patented 1839—The antiseptic used was crude pyrolignite of iron. Freshly cut timber with the terminal foliage remaining was set vertically or horizontally, with the foot immersed in the solution of antiseptic. Logs were placed on end and a tank was placed above it, containing the solution communicating with an air-tight bag surrounding the upper part of the log.

All kinds of deliquescent salt solutions were in this manner used by the inventor for different purposes

Fast dyes were applied to woods by successively introducing the dye and the mordant, and odorous solutions were used to give the wood fragrance

Beerizing consists in saturating timber with a solution of borax.

Folacci.—Uses the following composition to produce impermeability and incombustibility in wood.

Sulphate of zinc.	25	parts.
Potassa	10	"
Alum	20	"
Oxid of manganese	10	"
Sulphuric acid 60° B.	10	"
Water	25	"

With the exception of the sulphuric acid, mix the chemicals, heat to 113° F., 45° C. Add the acid gradually.

Margery.—Saturate wood with a solution of sulphate of copper. Very generally used for telegraph poles in France, Germany, Belgium, etc.

52. COLOR PIGMENTS FOR PAINTS, DYES, AND STAINS.

Their constituent

Minerals and Metal Compounds.

The shadings of all colors begin with *white* and end with *black* White may, therefore, be considered as the color from which all other colors emanate, and black as the one in which all others disappear

Any of the fundamental colors, white, black, yellow, red, and blue, may be modified by the admixture of one or several of the other colors and thereby may be formed composite colors, as, for instance, gray, brown, green, violet, etc.

White Colors.

Barium Sulphate, $BaSO_4$, is sometimes used as a pigment, ground finely from the mineral known as heavy spar, which for this purpose, after grinding, is levigated and dried.

Blanc fixe is a variety of barium sulphate obtained by precipitation, generally as waste material of other chemical operations It is largely employed in the paper-making industry. It has good body and covering power, is permanent in air and light, and is probably the whitest pigment in existence.

Griffith Zinc White is a combination of zinc sulphid, zinc oxid, and barium sulphate It works well with oil, has good body, and covers well, and is permanent in air and light.

Gypsum, $CaSO_4 2H_2O$, when white, precipitated or ground into a fine powder and levigated, may be used with water as a pigment. It is employed as filling for paper, cotton cloth, etc Permanent in air and light, it may be mixed with other pigments without producing changes. One part gypsum is soluble in 500 parts of water In boiling hydrochloric acid it becomes entirely soluble. Calcination at a low, red heat converts it into plaster of Paris.

Magnesite, $MgCO_3$.—In nature it occurs in compact masses; combined with carbonate of lime it forms the rock *dolomite.* Insoluble in pure water it becomes soluble in a solution of carbonic acid. As a finely ground and levigated powder it may be used as a pigment; only employed in a few mixtures.

Orr's White.—The result of a calcination of barium sulphate in a charcoal furnace, converting it into sulphid, dissolving

the barium sulphid out of the calcined mass by lixiviation with water, adding the resulting solution to a solution of zinc sulphate, drying, and carefully heating the resulting precipitate of a mixture of zinc sulphid and barium sulphate, so as to convert part of the zinc sulphid into zinc oxid This constitutes then a fine white pigment of very good body and covering power, mixing well with all vehicles and with other pigments, and is not discolored by sulphur fumes or by exposure to air and light Its composition in per cent is about 70 baryta, 15 zinc sulphid, and 13 zinc oxid

Satin White.—The precipitate resulting by boiling a solution of alum or of sulphate of alumina with lime water As a pigment it is fair in body and covering power It is an excellent material for paper staining or filling, producing by calendering a highly polished surface on the paper.

Spanish White.—A name given to a preparation of whiting or perhaps of white clay.

Strontium White, $SrSO_4$.—Similar in chemical composition to barytes and gypsum, from which it may be distinguished by the red color it produces in the Bunsen flame. Being rare it is hardly of use as a pigment.

Sublimed White Lead is the name given to a mixture of lead sulphate, with some zinc oxid and lead carbonate in a variety of proportions. As a pigment it has good body and covering power, is permanent in air and light, works fairly well with oil, and is not poisonous.

White Lead $2(PbCO_3)PbH_2O_2$.—Prepared by the usual industrial processes, of which there are a number, the principal of which is the corrosion process. It is generally obtained as a white powder and used as a pigment with oil and water; it is permanent in light and pure air, but will turn more or less brownish, and when used as a water-color, almost black, in moist air contaminated with sulphurous gases. It mixes well with oil and water, has very good body and coloring power, and may be mixed with all pigments free of sulphur, without producing chemical changes When sulphur is present it combines with the lead, producing lead sulphid, PbS, of a dark-gray color White lead is often adulterated with barytes. By dissolving a sample of white lead in *dilute* nitric acid, the pure lead carbonate is completely dissolved, leaving the barium sulphate as an insoluble residue.

Whiting, $CaCO_3$, Chalk, or Carbonate of Lime ground to a fine powder and levigated, is used in distemper, with water as a vehicle, for coloring walls and ceilings. With drying-oil worked into a stiff paste it constitutes putty. It mixes with all pigments which are not affected by alkalies. With a solution of glue, some drying-oil, and a large proportion of paper pulp it produces the material known as carton-pierre, which, pressed into molds and dried, is used for plastic interior decoration of rooms.

Zinc White, ZnO—As obtained by the combustion of zinc vapor and collected from the chambers and flues, in which it is deposited, it forms a pigment of a bluish-white color, mixing well with oil and other pigments. It covers well and colors fairly well. As a water-color it is known as Chinese white.

Black Colors.

Carbon Black, C—Collected from chambers and flues in which it is deposited from incomplete combustion of natural gas or of mineral oil; contains from 95 to 97 per cent of pure carbon, the rest being occluded gases and moisture. Mixed and ground with a good quality of drying-oil it makes fine printing and lithographing inks.

Bone-black, Ivory-black.—Bone in one and ivory waste or chips in the other case are calcined at red heat in a closed retort, admitting no air. The resulting black material, if intended to be used as a pigment is finely ground, and in the case of ivory-black mixed with a good drying-oil forms a much-prized fine black paint for artists. In the case of bone-black, which, used as a paint with drying-oils, has a brownish hue, the finely ground material is extensively used in the manufacture of blacking. In grains, bone-black is used for decolorizing sugar, glycerine, etc.

The composition of both in per cent is about 75 mineral matter and 17 carbon.

Lampblack, C—resulting from the incomplete combustion of any oil or fat, is deposited in specially constructed flues, from which it is collected. It mixes well with other pigments, with oil, water, or any other vehicle. It consists of about 94 to 95 per cent of carbon, the rest being water and a very small quantity of ash. Lampblack has no drying effect on the oil. Painting with it, therefore, dries slowly.

Yellow Colors.

Antimony Orange, SbS_3—A precipitate of bright-orange color resulting from the passage of sulphid of hydrogen through a solution of antimony chlorid. The dried impalpable powder constitutes a pigment mixing with other pigments, except such of alkaline nature or containing alkaline ingredients. It mixes well with oil and water, has good body and good covering powers, and is unaffected by air or light.

Antimony Yellow, Naples Yellow, is a compound of oxids of lead and antimony of bright-yellow color, with good properties as a pigment, but has of late largely been displaced by the cheaper chrome yellow

Arsenic Orange, Realgar, As_3S_2—Occurs in nature or is the result of sublimation of a mixture of sulphur and arsenic. Its light color, body, and covering power restrict its use as a paint to special cases only.

Arsenic Yellow, King's Yellow, Orpiment, As_2S_3—Found as a natural coloring-matter, it is made artificially by passing hydrogen sulphid through a solution of arsenious acid. As a pigment it is now rarely used.

Barium Chrome, Lemon Chrome, $BaCrO_4$ — A precipitate by mixing solutions of barium chlorid and potassium chlorate. Although permanent in air and light it is limited in use, having but slight body and coloring power.

Cadmium Yellow, CdS.—This pigment is the precipitate obtained by passing hydrogen sulphid through a solution of a cadmium salt. It mixes well with all vehicles, and as a paint has good covering power and remains unaltered in air and light. While it mixes with most pigments, it cannot be employed in admixture with pigments containing lead or copper. It is almost exclusively used by artists.

Chrome Yellow, $PbCrO_4$—Manufactured in various shades and tints, generally by the addition of a variable quantity of lead sulphate, $PbSO_4$. Such pigments mix with others free of alkaline substances or of sulphur, they mix well with oils and water, and have very good coloring and covering power. Some cheap chrome yellow may contain barytes, gypsum, or china clay as tinting medium.

Chrome Orange, $PbCrO_4$ mixed with lead oxid or lead sulphate, making it a chrome yellow modified in color by a variable addition of the oxid or sulphate mentioned

Ochre.—A bright yellow or reddish-yellow mineral of natural occurrence, of variable and complex composition, principally of hydrated oxid of iron, silica, and alumina. As a pigment, when finely ground and dry, it mixes with other pigments, with all vehicles, oily and watery; as a paint it has good body and coloring power and is durable and permanent on exposure to light and air.

Tin Oxid, Stannic Oxid, SnO_2—Manufactured as a pale yellowish powder; is principally employed for coloring glass and pottery yellow, and for enameling.

Zinc Chrome, $ZnCrO_4$—A yellow precipitate formed by zinc oxid in a boiling solution of potassium bichromate, or by adding to a solution of zinc sulphate a solution of potassium chromate It is of pale greenish-yellow color of but little coloring power and body.

Brown Colors.

Sepia.—It is a brown coloring-matter from the ink-bag of the cuttlefish. It is mainly employed as a water-color by artists.

Sienna in its raw condition is of a reddish or yellowish-brown color, but is mostly employed as a pigment when burnt Raw sienna finely ground, levigated, and dried makes a pigment which mixes with other pigment without change. It mixes well with oily and watery vehicles, is, as a paint, permanent in light and air; its coloring power and body are relatively slight.

Umber.—A natural pigment occurring in various shades of brown and of variable composition. Calcination makes the shade darker. Its composition in per cent may vary as follows: Silica, SiO_2, 12 to 30; ferric oxid, Fe_2O_3, 6 to 36; manganese dioxid, MnO_2, 10 to 12, to which may be added small proportions of alumina or lime. In some specimens the silica may be found to be replaced by barium sulphate up to 30 per cent and a little calcium sulphate. All umbers mix well with other pigments, and mix well with oil or water. As paints they have fair covering and coloring power and are permanent in light and air.

Red Colors.

Antimony Vermilion. Sb_2S_3—A scarlet-red precipitate from mixing solutions of antimony chlorid and sodium thiosulphate.

This pigment being a sulphid of a bright-vermillion color when employed for coloring vulcanized rubber, is unaffected by the sulphur in the rubber.

Carmine is a red-lake pigment derived from cochineal, and is of a very complex chemical composition. It mixes well with oil and with water containing some ammonia in solution, and forms a powerful staining paint of a bright crimson-red color. It is completely soluble in ammonia, but is insoluble in water and in alcohol. The color fades somewhat in light and air.

Carmine Lake derived from cochineal liquor after the extraction of carmine, is an alumina lake only partially soluble in ammonia, but soluble in caustic potash or in caustic soda. As a paint it works in oil or water, but the brightness of its red color faints by exposure to light and air

Derby Red, Chrome Red, Chinese Red, American Vermillion, $PbOPbCrO_4$—The result of decomposition of carbonate of lead in a solution of neutral chromate of potash. The powder obtained forms a pigment of a somewhat brilliant red color Mixed with oil it forms a paint, which, on account of the heaviness of the pigment, works with a little difficulty, with good coloring and staining power

Indian Red.—A dark-red pigment occurring in nature or prepared by calcination of ochres, of various composition, ferric oxid, Fe_2O_3, being the main coloring medium, which may vary in quantity in various samples between 44 and 95 per cent, the other ingredients being carbonate of lime, barium sulphate or clay. These pigments mix well with water and oil, and as paints have good coloring power They are mainly employed as stains. The pigments mix well with other pigments without provoking, or producing changes.

Red colors, under the names of *oxid red, vermilion red, turkey red,* are all similar to the above.

Rouge, or Colcothar, is a red oxid of iron obtained as the residual of the calcination of copperas.

Rose Madder, an alumina lake with an extract of madder of a rose color; a high-priced pigment mixing well with water and oil, and almost exclusively used by artists.

Rose Pink.—An alumina lake with an extract of Brazilwood on a base of some white pigment, mostly used for paper staining and wall-paper printing

Royal Reds are obtained by precipitating the coal-tar color, *eosine*, with lead acetate solution on a base of red lead or of barytes or of a mixture of the two in various proportions for modifications of tints This pigment mixes well with water and oil, but the color faints somewhat by exposure to light and air In alcohol and in methylated spirit the solution takes place with fluorescence and acquires a bright-scarlet color.

Red Lead, Pb_3O_4 — Orange lead, obtained by an oxidation process in specially constructed furnaces, is a bright-scarlet red pigment exercising a powerful drying effect on oil, with which it mixes well. As a paint it is considered to be the best material for grounding iron-work, as it preserves the iron from corrosion better than any other paint. On account of its drying property it is used as a cement in pipe-fitting for all purposes It is extensively used for electric storage batteries.

Sienna when burnt is of a bright, somewhat yellowish red. With the exception of loosing its combined water it does not differ in composition from the raw state. Its main component parts in per cent are ferric oxid, Fe_2O_3, 45 to 75, silica, SiO_2, 7 to 23, alumina, Al_2O_3, 1 to 15. Burnt siennas mix with other pigments without changing or provoking changes They mix well with water, oil, or methyllic alcohol. They are mainly used as staining colors, as while their coloring powers as paints are good, their covering powers are only moderate. They are permanent in light and air.

Vermilion, HgS — This sulphid of mercury occurring in nature is the principal ore for the production of the liquid metal mercury. It constitutes in its pure state a color pigment of a very fine scarlet red. Being very heavy, with a specific gravity of 8 2, it has a tendency to sink in the vehicle with which it is mixed. As a paint in oil it has good coloring and covering power and is permanent in air or light In water-color painting it has a tendency to turn brownish.

Vermilionettes.—These are lakes, made as substitutes for vermilion, of a rose to a dark-red color, and of a variety of compositions. In all of them the coloring matter is the coal-tar dye, *eosine*, of which about 1 per cent enters in pale, and 4 per cent in the composition of dark colors. The pigment is obtained by precipitating the coloring-matter from a solution of eosine by mixing it with a solution of a lead or of an alumina salt, onto a base of barytes, of barytes and red lead mixed

or on gypsum. These pigments have all good coloring power mix well with oil and water, fade somewhat in air and light

In alcohol or methylated spirit, the coloring-matter is dissolved, the base pigments remain at the bottom, where a fluorescent action can be observed, while the upper part will be colored a more or less pronounced rose.

Blue Colors.

Azurite, Mountain Blue, $2(CuCO_3)CuH_2O_2$—A basic carbonate of copper occurring in nature. Rarely used as a color pigment.

Cobalt blue, $CoO4(Al_2O_3)$, Thenard's blue, Gahn's ultramarine, cobalt ultramarine. This pigment mixes with other pigments without producing changes; as a paint it gives better results with water than with oil. It is permanent in air and light and unaffected by alkalies and dilute oxids.

Prussian Blue, FeC_3N_3, or $KFeC_3N_3$—The chemical composition varies in accordance with the manner of production. Varieties differing somewhat in tint and quality of color are known under the names of:

Chinese Blue, a very fine color with bronzy appearance.

Paris Blue of a slight violet hue; **Brunswick blue,** a mixture in various proportions with precipitated sulphate of baryta.

Mitis or Steel Blue, resembling in color ultramarine. All these color pigments mix well with oil; they mix also very well with water, and while they are very finely diluted in it, they are in reality not dissolved.

Soluble Blue a quality which will dissolve in water.

Prussian blues mix well with other pigments without being affected by them and without affecting them. Alkalies or alkaline vehicles, however, turn them brown. Applied as paint they faint somewhat in the light, recovering the color in the dark. While they have good coloring power their covering power is somewhat weak.

Smalt.—As manufactured in various tints and shades of blue it is essentially a double silicate of potash and cobalt, with a variable admixture of small proportions of lead oxid, calcium oxid, and alumina. Ground into very fine powder it mixes well with water and oil and is permanent in air and light.

Ultramarine.—Formerly obtained by a complicated process from the mineral lapis-lazuli, is now artificially manufactured

by calcining mixtures in varying proportions, composed principally of silica, white clay, soda, sodium sulphate, sulphur, and rosin, producing pigments of bright-blue colors of various shades and tints from greenish to violet blues The finely ground pigments mix well with others, are not affected by alkalics, but may be decomposed by acids They mix well with water and oil, and used as paint are permanent in air and light. They are extensively used for painting and for printing.

Green Colors.

Brunswick Green.—A pigment prepared by mixing Prussian blue, chrome yellow, and barytes in proper proportions to produce the desired tint and shade.

Chrome Green, Guignet Green.—The result of the fusion of a mixture of bichromate of potash and boracic acid. The green pigment thus produced is insoluble in water and acids, it is unalterable by alkalies or by moderate heat It mixes well with all vehicles. Employed as a paint it is permanent in air and light and has good covering and coloring power

Cobalt Green.—A green pigment of variable composition, the principal ingredients being zinc oxid, ZnO, and cobalt oxid, CoO, which are constituents in all kinds. To this in some kinds is added phosphoric acid P_2O_5 One green may, for instance, consist in ZnO, 88 per cent, and CoO, 12 per cent, and another in ZnO, 73, CoO, 19, P_2O_5, 8. These pigments mix well with other pigments, and with all vehicles, and as paints are permanent in air and light.

Emerald Green, Paris Green, Schweinfurth Green.—A copper acetoarsenite or a combination of copper oxid, CuO, arsenious acid, As_2O_3, and acetic acid, $C_4H_8O_4$ It is a pigment of a bright bluish-green color, which mixes well with other pigments free of sulphur It mixes well with oil or water, and as paint has good coloring and covering power, is fairly permanent in dry places, but is affected in air and light

It is soluble in acids and alkalies. Its solutions in hydrochloric acid are green, in ammonia deep blue, and in caustic soda blue

Malachite, Mountain Green, Mineral Green, $CuCO_2CuOH_2O$—A carbonate of copper occurring in nature, partly employed as a copper ore and as an ornamental stone; has also been

used as a pigment for green paint, for which purposes, however, it has been displaced by greens of superior quality

Terre Verte.—A natural green, principally composed of silica, SiO_2, 50 to 52 per cent, oxid of iron, FeO, 20 to 27, some magnesia, MgO, alumina Al_2O_3, which may be combined in one sample with caustic soda, in another with caustic potash, and in a third with caustic lime.

The pigment mixes well with all vehicles; has, however, little body; is, therefore, deficient in coloring power. Heat gives it a reddish hue.

53. GUMS AND RESINS for VARNISHES.

1. Fossil Gums and Resins.—Fossil gums are found under ground or under water, near sea coasts or in beds of streams.

Amber.—The main supply has so far been obtained from the Baltic-sea shore of northeast Germany It is extensively used for ornamental articles. In its natural state it is insoluble in any known vehicle. After having been melted it becomes soluble in turpentine and in boiling linseed-oil, producing a varnish of superior quality used as a coach varnish.

From the vapors of melted amber an oil can be distilled, known as amber-oil.

When polished it is translucent, of a light-yellowish color, sometimes with white specks covering parts of its mass Specimens have been found with insects incrusted in them.

Asphaltum, Bitumen of Judea.—Mined in many countries, it has been extensively employed as a very even covering for streets and for sidewalks It is soluble in many vehicles, in turpentine and in naphtha and produces a varnish of an intense black color.

Copal, Animi Gum.—It is found in many commercial varieties in many localities of the west coast of Africa. Melts at about 205° C (400° F), and is thereby converted into a hard brittle mass, which is soluble in ether, turpentine, chloroform, etc., and in hot linseed-oil, forming varnish of superior quality, extensively used for carriages and fine furniture.

Demerara Copal, Locust Gum, Guiana Gum.—Found in British Guiana It melts at about 240° to 250° C (450° to 465° F), and in so doing, gives off a considerable proportion of volatile oil and of gas The resulting hard brittle mass is soluble in ether. It swells up to a gelatinous mass in alcohol and chloroform and forms a white jelly in petroleum.

Kauri, Cawree.—Found on the Island of New Zealand exported from Aukland; is of a pale yellowish-brownish color of a glassy to opaline lustre, conchoidal fracture, and pleasant aromatic odor and taste. It melts at from 180° to 230° C (360° to 450° F.), and after melting becomes easily soluble in oil, producing a good varnish for furniture and inside work It is completely soluble in ether, and, after having been melted, losing thereby about 25 per cent of its weight, it is soluble in turpentine, petroleum spirit, benzol, and chloroform, in which before this process it was only partially soluble, being mainly converted into a gelatinous mass, the same effect being produced in alcohol.

2. Recent Gums and Resins.—**Damar, Gum Damar,** from Siam and vicinity is a brittle almost white-yellowish translucent resin, soluble in oil, turpentine, petroleum spirit, ether, chloroform. In alcohol it swells to a white gelatinous mass Used as varnish for maps and ornamental articles, etc., on account of its limpidity and clearness.

Dragon's Blood.—From eastern Asia; is soluble in alcohol, benzol, petroleum spirit, shale spirit, acetic acid, caustic soda, ammonia, chloroform, carbon bisulphid, etc., the solutions being of a crimson color. It dissolves with difficulty in ether and is almost insoluble in turpentine. It melts at about 120° C (248° F.). In a powdered condition it is employed for coloring varnishes a deep red.

Gamboge.—Principally from Siam, it is a gum resin of a bright-red color. The resin in gamboge is soluble in alcohol, ether, chloroform, and in alkaline solutions. The gum is soluble in water. It is principally used as a yellow water-color.

Gum Mastic.—It is obtained from some parts of the coast and from some islands of the Mediterranean Sea. It is brittle, of conchoidal fracture, and softens at about 30° C. (86° F.), melts at from 105° to 120° C. (221° to 248° F.). It is soluble in turpentine, alcohol, amyl alcohol, chloroform, acetone. Insoluble in ether. It is used as a varnish.

Gum Accroide.—A resin which dissolves in alcohol.

Gum Arabic is insoluble in alcohol; in about $1\frac{1}{2}$ times its weight of water, with the help of gentle heat, it is converted into a viscous jelly, which becomes more adhesive by the addition of a little sulphate of alumina. Used as an adhesive for various colors and for other purposes.

Gum Benzoin softens at about 75° C (167° F.), melts at 100° C. (212° F.). Soluble in alcohol and ether and employed as spirit varnish.

Gum Elemi is obtained from the Philippine Islands It softens at about 75° to 80° C (167° to 176° F.), and it melts at 120° C (248° F.). It is soluble in ether but only partially soluble in alcohol.

Lac, Shellac, Button Lac, Garnet Lac.—As obtained from India it is partially soluble in alcohol and methylated spirit, with either of which, however, it forms a very extensively employed spirit varnish, which on account of its quick drying property, its good covering power, and easy application is nearly exclusively used for patterns of machinery Such varnishes are also used for inside woodwork and as a polish for fine furniture. Shellac is soluble in amyl alcohol (fusel-oil), in solutions of caustic potash, of caustic soda, of borax, and of ammonia, the latter of which are used as varnishes and dressings for leather.

From alkaline solutions bleached lac is precipitated by chlorin gas.

Manilla Copal, obtained from the Philippine Islands, melts at about 115° C. (240° F.). This resin is soluble in alcohol, methylated spirit, ether It is partially soluble in amyl alcohol, benzine, petroleum spirit, turpentine, chloroform, leaving generally a residue of a white gelatinous mass It is useful for spirit varnish, which added to shellac varnish imparts to the dry coat more elasticity

Rosin is the residue left after turpentine has been distilled from pine resins. When cold it is brittle, of a yellowish light-brown color and characteristic odor It is largely employed for cheap inferior varnishes, produced by dissolving it in rosin spirit, in turpentine, or in naphtha, or by mixing melted rosin with boiling linseed-oil

Sandarac, Gum Juniper, is a hard and brittle resin of a yellowish-white color, which melts at 150° C (300° F.) It is soluble in alcohol, methylated spirit, amyl alcohol, ether;

slightly soluble in benzol, petroleum spirit, turpentine, in which it becomes soluble after having been fused. It is manufactured both into spirit and into oil varnish, forming bright, lustrous, hard, and durable coats when dry.

Turmeric, Curcumin, obtained from the roots of curcuma in hot solution from which orange-red colored needles crystallize out on cooling. This yellow coloring-matter is soluble in hot, but only slightly so in cold water It is soluble in alcohol, in glacial acetic acid and in solutions of alkalies, which change its color to brown-red In boric acid solutions the color turns brown It is employed for staining and for coloring varnishes yellow, and is in use as a dye, cotton being dyed by it without a mordant.

54. DILUENTS AND SOLVENTS

for Paints and Varnishes.

Drying-oils, which are the only ones which can be used for paints, absorb oxygen at the surface exposed to the air, whereby an elastic tough film is produced. When such oil, forming a vehicle for some coloring pigment, is spread out over a surface as paint, it is, by its property of absorbing oxygen from the air, wholly converted into such a film, which in drying constitutes a hard, horny protection for the surface painted.

Spirits and **alcohols** dry without leaving any residue. When they contain gums and resins in solution, however, forming varnishes, they leave the gums and resins behind in drying. Some spirits are employed in the art of painting as diluents for paints, serving at the same time as promoters for drying.

Hempseed-oil is a slow-drying oil of inferior quality as a paint oil. It has, however, been used as such in exceptional cases.

Linseed-oil, raw and refined, at ordinary temperature, is clear and limpid, of a yellowish-brownish color. It is soluble in alcohol at the rate of 1 volume of oil in 40 volumes alcohol cold, and in 5 volumes alcohol boiling. It is also soluble in turpentine, petroleum spirit, shale naphtha, rosin spirit, ether, chloroform, etc

By warming a mixture of raw linseed-oil and glacial acetic acid (99 per cent pure), above 60° C. (160° F), the oil is dis-

solved, but separates again from the solution on cooling, and from 47° to 36° C (117° to 97° F), a turbidity in the solution is produced, which disappears again on further cooling.

If adulterated, the oil is not completely dissolved and the turbidity occurs much sooner.

The value of linseed-oil as a vehicle for paint is dependent on its oxygen-absorbing capacity, which varies between the maximum of 190 volumes of oxygen absorbed by one volume of Baltic oil, and the minimum of 130 volumes of oxygen by one volume of Bombay (India) oil American linseed-oil absorbing about 160 volumes of oxygen.

The solid elastic film produced by drying linseed-oil is insoluble in water and in alcohol. It is only partially soluble in ether or chloroform.

Boiled Linseed-oil.—By keeping raw linseed-oil at a temperature of about 260° C. (500° F) for several hours, and by adding to the oil from 1 to 2 per cent of a so-called dryer, which may consist of manganese peroxid, litharge, red lead, or any other oxidizing substance or a mixture of several of such substances, the oil may be brought to a more or less thick or viscid consistency, in which condition it has the property to dry much quicker than in its raw state

The heating may be performed over a fire, producing a comparatively dark oil, or by steam with the production of a paler oil

In the use of boiled linseed-oil as a vehicle for color pigments, it is often mixed with raw oil, which, while the drying is retarded, produces a more elastic paint film on the painted surface.

Menhaden-oil, obtained from a fish, abundant along the east coast of North America; has a brownish color Its principal employment consists in leather dressing. Occasionally it is used as a paint-oil, as it dries well in air, leaving a hard film behind.

Poppyseed-oil, a drying but costly oil, used only by artists.

Rosin-oil is the last distillate from rosin, the first being an acid liquid, the second a light rosin spirit, the third a heavy rosin-oil, which after being refined by successive treatments with sulphuric acid and caustic soda, is sometimes employed as an adulterant of linseed-oil Paint made with such adul-

terated oil may dry all right, but it will subsequently become sticky

Walnut-oil is a clear straw-colored drying-oil used by artists.

Alcohols and Spirits.—Alcohol, Ethyl Alcohol, Spirit of Wine. It is a solvent for shellac, sanderac, rosin, camphor, castor-oil, coal-tar colors, etc. It mixes with water, turpentine, ether, chloroform, carbon bisulphid, benzol, etc.

Amyl Alcohol, Fusel-oil, dissolves many resins, essential oils, camphor, etc. It mixes with water, 1 part in 11 parts water In indefinite proportion with alcohol, ether, chloroform, carbon bisulphid, petroleum-ether.

Benzol, Benzine. A hydrocarbon derived from petroleum; dissolves oils, fats, resins, mixes with alcohol, turpentine, petroleum-spirit, ether, etc.

Benzoline is a solvent for oils, fats, waxes, and for a number of resins. Mixes like benzol.

Gasolene has the same properties as the foregoing hydrocarbons.

Methyl Alcohol. By distillation of wood, the liquid wood spirit is obtained; this is converted into methyl alcohol by a rather complicated purification process. It is a colorless liquid which mixes in all proportions with water, turpentine, ether, etc., and dissolves most gums and resins with which it forms varnishes of extensive use.

Methylated Spirit is a mixture of 90 per cent alcohol (wine spirit), with 10 per cent wood spirit principally used for shellac varnishes and polishes, for damar, sanderac, rosin, and other resinous varnishes.

Naphtha.—A distillate from coal tar, properly purified, is a good solvent for oils, resins, waxes, coal-tar pitch, wood pitch, and mixes with ether, alcohol, turpentine, petroleum spirit, etc Several naphthas are in use, all having the same solvent and mixing properties. They are known as:

Wood Naphtha, or refined wood spirit.

Shale Naphtha a refined distillate from shales.

Petroleum Naphtha, Petroleum Spirit, obtained by fractional distillation of crude petroleum.

Benzine and benzoline are names applied substantially to the same, or closely similar distillates from petroleum, as is also gasolene. All are fractional distillates from petroleum and differ only in specific gravity.

Turpentine.—This, for the painter, most important spirit, is the distillate from pine resin, obtained by blowing steam through melted crude pine resin. It mixes with alcohol, ether, carbon bisulphid, and with all petroleum distillates and with water. It is a solvent for fats, oils, gum resins, waxes, etc In air it partly evaporates and partly absorbs oxygen, whereby it is converted into a hard resinous substance It is so far the best material in use as a solvent for varnishes of the various commercial gums and resins, and as a diluent and drier, for paint. It is often adulterated, usually with rosin spirit, petroleum spirit, shale naphtha, coal-tar naphtha, etc. Pure turpentine has a specific gravity of 0.864 to 0.870, average 0.867. It boils at 156° to 160° C. (313 to 320° F.), and distills completely without leaving any residue at 170° C. (338° F.).

55. MISCELLANEOUS.

Marine Glue.—India rubber, 1; coal-tar naphtha, 8 to 12; and shellac, 15 to 20 parts. Melt together; use hot.

Water-proof Glue.—Boil about 8 parts of common glue in about 30 parts of water, add 4½ parts boiled linseed-oil, continue boiling for 2 or 3 minutes while stirring.

Japan Varnish.—Parts by weight. Boiled linseed-oil, 88; litharge, 4; red lead, 6; sugar of lead, 2; umber, 1; white vitriol, 1; gum shellac, 8; spirits of turpentine, 2. Mix all the ingredients except a small portion of the boiled linseed-oil and all the turpentine Boil over a slow fire for 5 hours, stirring continually with wooden spatula; add occasionally boiled oil to check ebulition. When nearly cool, add turpentine, stirring it well in Keep in tightly corked cans.

Boiled Linseed-Oil.—Preparation. Parts by weight. Raw linseed-oil, 103; copperas, 3.15; litharge, 6.3. Suspend the copperas and litharge in the oil in a cloth bag, and boil slowly for about 4½ hours.

Dryer for Paint.—Parts by weight. Copperas and litharge from boiled oil, 60; boiled oil, 2; spirit of turpentine, 56. Grind and mix thoroughly

Considered to be useful as driers for boiling linseed-oil are the following:

Manganese Dioxid, Manganese Peroxid, Black Oxid of Manganese, Pyrolusite, all names for the same substance, yields

oxygen by heat and is therefore added to the boiling oil in quantity of about ½ to 1 per cent of the oil, but darkens the color of the oil.

Manganese Linoleate, which is obtained by pouring a solution of manganese sulphate in a caustic-potash linseed-oil soap solution. The curdy mass produced is filtered, washed, and dried, and is used in this condition as a drier and bleacher for boiling linseed-oil.

For the production of pale oils and for imparting to the boiled oil the property of drying.

Manganese Sulphate, $MnSO_3$, a faint pinkish-colored salt has also been found useful.

Black Stain for Wood.—Copperas, 1 lb.; nutgalls, 1 lb.; sal ammoniac, 0.25 lb.; vinegar, 1 gallon. Mix and stir occasionally for a few hours. Apply the stain to a cleaned surface of wood 2 or 3 successive times; when dry rub with boiled oil; polish.

Mortars, Concretes, or Betons

for Masonry and Foundations.

Designation	Parts by Volume					Water
	Sand	Lime	Hydraulic Lime	Cement	Broken Stone	
Common mortar	3 to 5	1				For stiff paste
Hydraulic-lime mortar	3		1			
Cement mortar	2 to 3			1		
Concrete	3 to 5	1			3 to 6	
Beton Croton Aqueduct	3			1	3	
Beton Coignet	20	4	1 to 2			
Cement concrete	3			1	4 to 7	

Sizes of Brick.

Designation	Size in Inches	Designation	Size in Inches
British legal standard	8¾ × 4¼ × 2¾	Colabaugh	9¼ × 3 + 2¾
United States, average	8¼ × 4 × 2¼	Maine	7½ × 3⅜ × 2⅜
U. S. press-brick paving	8 × 4 × 2¼	Milwaukee	8½ × 4⅛ × 2⅜
Baltimore front	8¼ × 4⅛ × 2⅜	North River	8 × 3½ × 2¼
Philadelphia	8¼ × 4⅛ × 2⅜	Fire-brick, Stourbridge	9¼ × 4¼ × 2½
Croton	8½ × 4 × 2¼	Fire-brick, American	8¾ × 4¼ × 2½

Fire Clay.

Average Composition.

Silica	Alumina	Protoxid of Iron	Lime	Magnesia	Potash
59.8 to 70.3	35. to 26 4	3 to 1	1.4 to 0 4	0.3 to 0.4	2.2 to 1.4

Preservative of Cut Stone.

Wall Surfaces.

Apply to the wall surface to be treated alternately coats of a solution of sodium silicate, followed by lime water; repeat two or three times. This will produce a hard coating of silicate of lime.

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